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Wood Preserving Industry Multimedia Emission Inventory

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Restriction of the discharge of wastewater generated during the preservation of wood has resulted in the increased use of evaporation techniques by the wood preserving industry. This report discusses emissions that may occur during evaporation and projects the pollutant burden on the environment. The information presented includes a description of the wood preserving industry, its products, the regulations impacting its emissions, and the nature of its emissions. The application of preservatives is discussed in detail and includes discussions of the waste streams generated during the treatment process. Disposal of the generated wastewater is the primary topic of discussion, supported by laboratory and field sampling data. The measured emissions are compared to evaporation models, followed by an industrywide projection of the emission of organics if evaporation is used for the disposal of wastewater. The impact of regulations on future emission rates is also projected.

The primary conclusions of this work are that organic compounds are emitted to the atmosphere during evaporation. The rate of release is based on the type of evaporation system used: solar ponds, thermal (pan) evaporators, spray ponds or cooling towers; the temperature (thermal) driving force used; the molecular weight and volatility of the substances; and the concentration of each component in solution following wastewater pretreatment.

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Contract 68-03-2584
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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report documents a recently completed project. Its purpose was to qualitatively and, whenever possible, to quantitatively assess the organic emissions resulting from the evaporation of wastewaters generated by the wood preserving industry. The findings in this report can be used to determine the driving forces governing the loss of organic constituents to the atmosphere and to project the mass emissions that can occur. The information contained in this report can also serve as a basis for future work. For further information, contact the Food and Wood Products Branch, IERL, Cincinnati, Ohio.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

Restriction of the discharge of wastewater generated during the preservation of wood has resulted in the increased use of evaporation techniques by the wood preserving industry. This report discusses emissions that may occur during evaporation and projects the pollutant burden on the environment. The information presented includes a description of the wood preserving industry, its products, the regulations impacting its emissions, and the nature of its emissions. The application of preservatives is discussed in detail and includes discussions of the waste streams generated during the treatment process. Disposal of the generated wastewater is the primary topic of discussion, supported by laboratory and field sampling data. The measured emissions are compared to evaporation models, followed by an industrywide projection of the emission of organics if evaporation is used for the disposal of wastewater. The impact of regulations on future emission rates is also projected.

The primary conclusions of this work are that organic compounds are emitted to the atmosphere during evaporation. The rate of release is based on the type of evaporation system used: solar ponds, thermal (pan) evaporators, spray ponds, or cooling towers; the temperature (thermal) driving force used; the molecular weight and volatility of the substances; and the concentration of each component in solution following wastewater pretreatment.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

API -- American Petroleum Institute
AWPA -- American Wood Preserver's Association
AWPI -- American Wood Preservers Institute
CCA -- chromated copper arsenate
CFAP -- fluor-chrome-arsenate-phenol
COD -- chemical oxygen demand
EGD -- Effluent Guidelines division
EPA -- Environmental Protection Agency
FWPCA -- Federal Water Pollution Control Act
GC/MS -- gas chromatography/mass spectrometry
I. Hygn -- Industrial Hygiene Branch
IERL-Ci -- Industrial Environmental Research Laboratory, Cincinnati
IERL-Inci. -- Industrial Environmental Research Laboratory, Incineration Branch
kg -- kilogram
l -- liter
LP -- liquified petroleum
m -- meter
MERL -- Municipal Environmental Research Laboratory
mg -- milligram
NCASI -- National Council for Air and Stream Improvement
ng -- nanogram (10^{-9} gram)
NIOSH -- National Institute for Occupational Safety and Health
OCDD -- Octochlorodibenzo-p-dioxin
OPTS -- Office of Pesticides and Toxic Substances
OSHA -- Occuptational Safety and Health Administration
OSW -- Office of Solid Waste
OWQPS -- Office of Water Quality Planning and Standards
PAH -- polynuclear aromatic hydrocarbons
PCB -- polychlorinated biphenyl
PD -- Position Document
penta -- pentachlorophenol
PFB -- pentafluorobenzyl
POTW -- publicly owned treatment works
ppb -- parts per billion
ppm -- parts per million
RCRA -- Resource Conservation and Recovery Act
RPAR -- retuttable presumption against registration
TCDD -- tetrachlorodibenzo-p-dioxin
USDA -- United States Department of Agriculture

ABBREVIATIONS AND SYMBOLS (Concluded)

SYMBOLS

μg	-- micrograms

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SECTION 1

INTRODUCTION

Wood preserving is a significant, diverse, and well established industry with approximately 475 operating plants in the United States. The principal product of these plants is chemically treated wood for use as utility poles, railroad ties, and construction materials. The industry is composed of both large and small plants with a total employment exceeding 10,000 in 46 states. Over 250 million ft^3 of wood is treated annually in the United States.

Wood is chemically treated to reduce or prevent decay by microorganisms, attack by insects, and fire. Adequate preservation requires the use of large quantities of chemicals (i.e., 0.8 lb of oil or creosote per cubic foot of wood). Chemicals used to treat the wood are toxic, and waste from these plants can cause environmental problems. Wastewaters are generated as a result of preservatives used, plant operations, surface runoff, and excess process water discharge. Solid residues include waste sludges from wastewater treatment, insoluble inorganic materials from waterborne salts, and contaminated soils from spills or drippage.

Efforts to control the adverse environmental impacts include both wastewater and solid residue discharge control by EPA as well as various states. Regulatory requirements of the industry currently prohibit wastewater discharge, and residue disposal is limited to approved disposal sites using specified handling techniques.

Industry's technical response to requirements for control of process chemicals has included increased recycling and evaporation of water to decrease aqueous discharges. Inadvertently, air emissions may have been increased. The primary purpose of this report is to determine the multimedia impact of evaporation technology on environmental quality.

This program was initiated by EPA's Office of Research and Development by issuing Acurex two work assignments. The first assignment involved the sampling and analysis of chemical losses during wastewater evaporation. Wastewaters containing two major wood preserving chemicals, creosote and penta, were tested. The second task was a survey of the industry, treatment technology, disposal technology, and to generate an inventory of projected emissions.

The engineering tasks required by these work assigments are outlined in the following list. Two major topics, and industrial profile and the results and modeling of test programs on wastewater evaporators, were to be combined into a single report.

Literature Survey

- Theoretical model development -- evaporation
- Evaporator design and operating variables -- to allow a reasonable understanding of plant operations and the variables affecting emissions
- Plant identification -- where samples can be obtained and an evaporation system tested
- Analytical and sampling techniques -- work associated with finalizing the analytical techniques and field testing procedures

Thermally Enhanced Evaporator Simulation

- Work associated with sample collection, apparatus parts and assembly, sample collection and analysis

Evaporator Field Testing

- Work necessary to measure air emissions from an operating evaporation system

Analytical Procedures

- Analysis of 14 samples from prior tests for polychlorinated dibenzo-p-dioxins
- Samples to include: Wastewater before evaporation, gaseous emissions during evaporation, and solid residue after evaporation

Establish Industry Business Trends

- Review present sales volume for penta- and creosote-treated products
- Obtain historical sales data for water- and oil-based products

Review Regulations

- Review present and pending federal, state, and local regulations, and define the requirements to be met by the wood preserving industry
- Assess impact on future plant operations and control techniques

Determine Representative Plant Data

- Review NCASI, AWPA, and regional EPA plant information
- Estimate number of plants and treatment methods
- Estimate wastewater generation rate
- Estimate plant size
- Establish criteria to measure regulatory action impact

Waste Control Options Summary

- Summarize waste control options: untreated to municipal sewers, evaporation ponds, forced evaporation ponds (spray), thermal evaporators, and cooling towers

Calculation of Emission Rates

- Estimate mass flowrates of waste materials
- Couple flowrates with treatment methods
- Estimate mass emission rates to all media

Emission Inventory Data

- Calculate load factor based on business outlook and expected use of penta and creosote
- Estimate emission inventory for any year to extent of reliable business and operational trends
- Survey ongoing programs related to topical areas covered by these work directives and identify data gaps

Final Report

- Theoretical developments and actual data collected
- The correlation of data to the models
- Prepare final report documenting all business and operational trends, waste treatment practices, emission inventories
- Discuss ongoing programs and identify data gaps and areas of uncertainty and recommend the research required to fill these gaps

Sections 2 and 3 present the conclusions and recommendations which have resulted from the completion of this work. Section 4 begins with the broadest discussions describing the industry, the regulations that impact it, and its past and projected business trends. As many descriptive areas as possible are included in the discussions that are intended to lead the reader to a clear understanding of this industrial segment.

Section 5 discusses the techniques for preservative application. Since the final result of this study will be a review of wastewater evaporation technology, any treatment process that did not generate a continuous wastewater stream was eliminated from further discussion. Therefore, waterborne salt and nonpressure-treatment proposes are not discussed.

To further limit the scope of the report, Section 6 deals with wastewater disposal technology, wastewater treatment, and the resulting air and solid discharges. Again, the goal of this report is to describe evaporative technology and its projected impact on the atmosphere. Therefore, the discussions of nonevaporative wastewater treatment are minimized, but presented for purposes of continuity and clarity. The primary purpose of Section 6 is to present the results of air emission testing from evaporation devices and present the mathematical models necessary to describe the results obtained.

Sections 7 and 8 describe the total industry emission burden on the atmosphere that may result from extensive use of evaporative technology, followed by a discussion of the data gaps and other programs presently being conducted by EPA and other groups.

Two appendices were necessary to limit the specific analytical and sampling programs discussed in the body of the report. These discussions included the detailed sampling and analysis procedures for the pan evaporator test program and the cooling tower test program.

For more information concerning the word preserving industry, the following list presents groups that can supply information:

- American Wood Preservers Association
  Bethesda, Maryland
  301-652-3109
  Secretary/Treasurer -- John D. Ferry

  The American Wood Preservers Association is a technical society that publishes standards for preservatives used in the treatment of wood, as well as standards for the treated products. These standards are intended to be used by the industry itself and to guide the purchaser in specifying and obtaining adequately treated wood. The Association has 2,000 individual members representing all phases of the wood preserving industry.

- American Wood Preservers Institute
  McLean, Virginia
  703-893-4005
  President -- Loren F. Dorman

  The American Wood Preservers Institute serves the industry, architects, engineers, and other users by providing services and information in the fields of marketing and technology, as well as governmental and environmental affairs. The 100 member companies are served by regional offices and the Arlington, Virginia headquarters.

- American Wood Preservers Bureau
  Arlington, Virginia
  703-931-8180
  President -- Charles E. Thomas, Jr.

  The members of the Bureau are all manufacturers of treated wood products who together pay the Bureau to inspect the industry and the products manufactured according to the standards set by the American Wood Preservers Association. This assures quality control throughout the industry.

- Society of American Wood Preservers
  Arlington, Virginia 22209
  703-841-1500
  President -- George K. Eliades

  The Society of American Wood Preservers was founded in 1958 to serve that segment of the industry dealing with waterborne salt treatment of wood. Their 100 members are located in the United States, South America, and England. The Society promotes the use of treated wood by contractors and building inspectors and keeps their members informed of government programs and regulations affecting their business.

- Southern Pressure Treaters Association
  Shreveport, Louisiana
  318-861-2479
  Executive Director -- J. Warren Sullivan

  The Southern Pressure Treaters Association serves only that segment of the industry represented by pressure treaters in the southeastern states. The two main functions of the Association are to compile statistics on raw wood supplies and demand for treated products, and to conduct college seminars to educate engineering students in the use of pressure treated wood.

- Southeast Lumber Manufacturers Association
  Forest Park, Georgia
  404-361-1445
  President -- John C. Milliner

  Since it is primarily a trade association for lumber manufacturers, this Association oversees timber supplies and promotes lumber use and wood products for its members. Approximately 10 percent of the membership is drawn from the wood preserving industry, and the Association sponsors a subcommittee that monitors and disseminates information.

SECTION 2

CONCLUSIONS

Organic constituents contained in wastewater from pressurized wood preserving processes using organic preservatives can be emitted to the atmosphere during wastewater evaporation. The fraction of organics emitted depends on several variables, including:

- Evaporation mechanism employed
- Thermal driving force for evaporation
- Molecular weight of the substance
- Pretreatment activities including pH adjustment and filtration

Pan evaporation tests representing a high thermal driving force for evaporation were conducted in the Acurex laboratory. These experiments showed that fractions of the organic constituents present, including penta, naphthalene, phenol, and other nonvolatile organics were discharged to the atmosphere. Although octachlorodibenzo-p-dioxin (OCDD) was present in the wastewater, it was not detected in the air emission samples collected.

Another type of evaporation device, a cooling tower, representing a low thermal driving force device, was also tested. Phenol was the only organic material emitted in the air stream. Other organics, such as penta, creosote constituents (PAH's) and OCDD, were present in the tower sump. The cooling tower represents a lower source of emissions than the pan evaporator and may be lower than spray pond systems (not tested) because atomization and drift are expected to be less.

For a given pH value, the effect of molecular weight on the evaporation losses also was determined. As the molecular weight increased, the potential for evaporation decreased. As thermal driving force increased, increasingly higher molecular weight substances were evaporated.

Acidifying the wastewater (to pH 2), coupled with filtration, significantly reduced the volume of organic material available for evaporation. The pH depressed the solubility of the organics allowing the resulting precipitates to be removed by filtration prior to evaporation. Contrarily, high pH values (greater than 10) resulted in low filtration efficiency and high evaporation losses.

On an industrywide basis, it is projected that approximately 20,000 kg/yr of organic material may be discharged to the atmosphere when wastewater is evaporated. These emissions consist primarily of volatile organics. If thermal evaporation techniques are used, the emission rate will be increased as the nonvolatile components are discharged. The projected usage of creosote is expected to decline slightly and penta and waterborne preservatives to increase slightly, resulting in the continued emission of organics to the atmosphere for the near-term future.

SECTION 3

RECOMMENDATIONS

To better qualify the mass emissions from wood treating sources, it is recommended that sampling and analysis studies be initiated to further evaluate the fraction of organic emissions from thermal evaporation devices and spray ponds. The data collected should be used to further evaluate the effects of solution pH, molecular weight, and thermal driving force for each evaporation device applicable to wastewater disposal. In addition, further testing characterizing fugitive emissions should also be conducted. This is especially necessary for gases that have come in contact with the preservatives that are discharged at elevated temperature and pressure. Fugitive emission sources include the retort vents, hoods, retort doors, and storage vessels. All work quantifying organic emissions should be directed toward refining the models presented in this report to allow for a complete understanding of driving forces affecting the mass emission rates of organic pollutants.

To qualitatively determine each component potentially discharged during the evaporation of wastewater containing creosote, careful separation of creosote into basic, acidic, and neutral extractables should be conducted to identify the species present in the coaltar-derived mixture. Other analytical activities include the disapperance of OCDD during cold storage. In addition, analytical work to qualitatively identify organic components contained in surface runoff should be conducted.

Solar evaporation ponds, the most widely used evaporation devices, should be tested to confirm the release of volatile components. Other field testing activities recommended include the evaluation of oil-water separators. This work should be designed to maximize the removal of free oils from the wastewater, thus ultimately reducing the emission of organic species.

SECTION 4

INDUSTRY PROFILE

Future growth of the wood preserving industry, coupled with regulatory activity and wastewater treatment procedures at each plant, will directly impact the mass emissions of pollutants discharged. The following discussions present a brief analysis of the historical trends and developments within the wood preserving industry, a review of regulations impacting the industry, and the related health and environmental impacts associated with the preservatives used to treat wood. This section presents the information used for the projection of the future growth of the industry, which will be used to project future multimedia pollutant burdens.

4.1 HISTORICAL DEVELOPMENT OF PROCESSES

The wood preserving industry, as it is known today, has been steadily evolving since the turn of the century. The products resulting from various treatment processes are used as railroad ties, utility poles, and construction materials.

The need to protect wood from various forms of decay and physical weathering has been recognized since ancient times. The actual use of chemical preservatives to perform this function did not come into widespread use in this country until the early 1900's. At that time, the expansion of railroad systems throughout the country created a need for a durable, weather-resistant material from which railroad ties could be made. Wood treated with creosote, an oily liquid mainly consisting of aromatic hydrocarbons, was found to fill this need, resulting in the large-scale use of creosote-treated products.

The need for a building material that could survive in marine environments presented another use for preserved wood. Again, creosote was found to be effective in most instances, providing protection to docks, underwater posts, and wharfs. However, attack by the marine borer, limnoria tripunctata, commonly known as "gribble" (References 1 and 4) can destroy creosote-treated wharfs. This resulted in further research into the use of chemical wood preservatives, leading to the discovery that a dual treatment of copper arsenate salts followed by creosote was successful in resisting gribble attack.

With treated wood products successfully demonstrated, utility companies, construction companies, steamship lines, road maintenance organizations, and various other groups saw potential uses for treated wood.

These uses would ultimately include such products as poles, pilings, plywood, fence posts, guardrails, bridge structures, boardwalks, and other lumber and timber products. New demands for treated wood created a need for more versatile products and a much greater output.

There was also a need for a clean, more paintable product not having the appearance or odor of creosote-treated wood. Therefore, an intensified search for alternatives to creosote was undertaken. Two types of preservatives were identified to achieve this: waterborne preservatives -- inorganic salts in a water carrier, and pentachlorophenol (penta) -- a crystalline compound applied in a light oil carrier. Both provided the protection similar to creosote while producing a product that could be used in many applications where creosote-treated products could not.

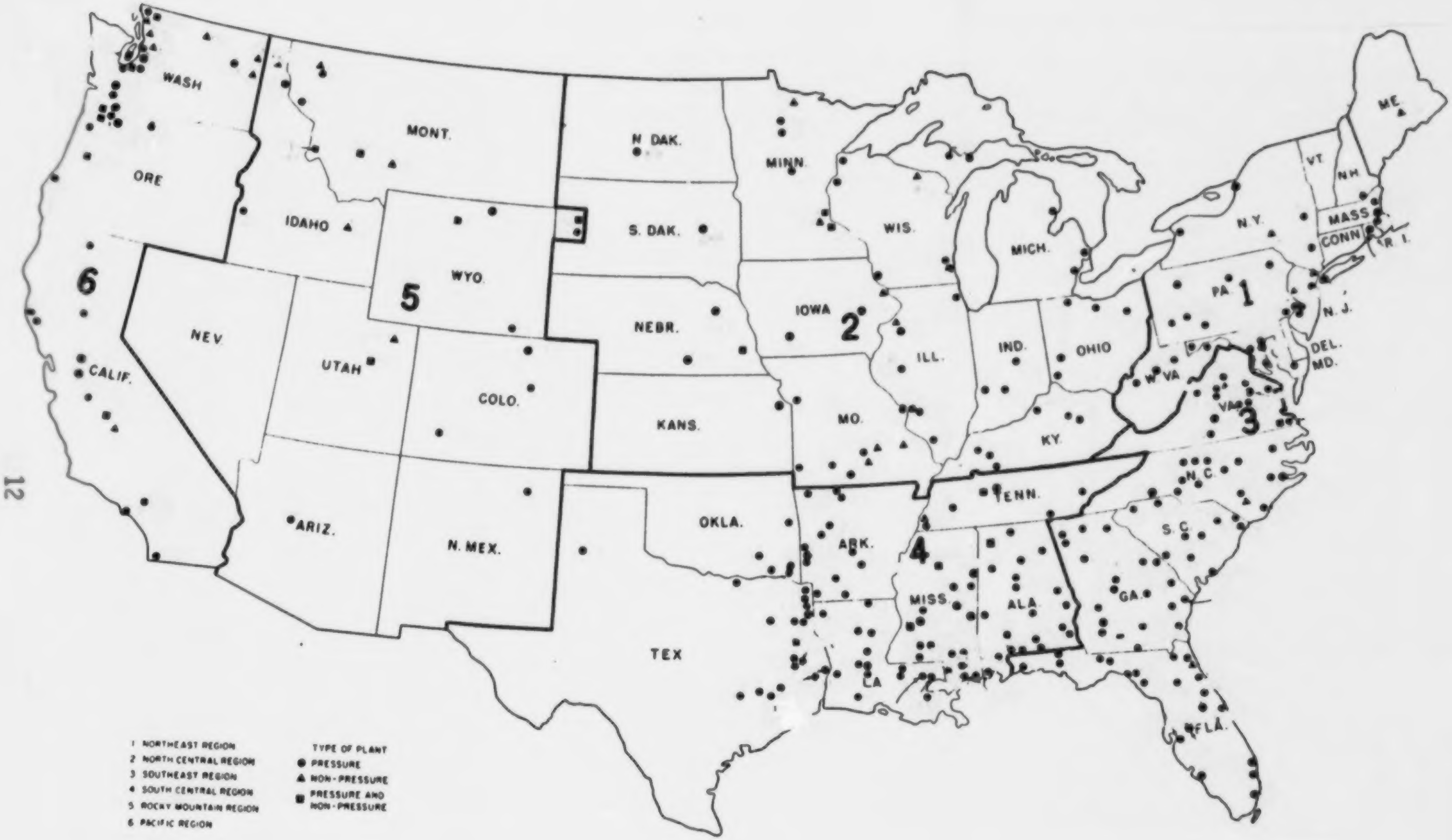
Presently, the wood preserving industry still uses the same three types of preservatives: creosote, waterborne salts, and penta. While research concerning new preservatives or alternate methods is continuing, new preservatives are not considered realistic options for the near term due to long periods of required testing. Therefore, the industry is dependent on the preservatives presently in use.

4.2 PRESERVATIVE USAGE AND INDUSTRIAL GROWTH

The wood preserving industry consists of those facilities treating wood with preservatives in retorts or open tanks. Approximately 300 companies using these processes at approximately 475 plants (References 2, 3, and 30) have been identified by company and plant location. The plants are distributed from eastern Texas and Oklahoma through the southeastern and mid-Atlantic states and the Pacific Coast as shown in Figure 1. Recent work by EPA's Office of Pesticides and Toxic Substances, has identified over 600 wood preserving plants in the United States (see Section 8). Users of preserved wood include the railroad, utility, and construction industries.

Creosote is produced as a distillate of coal tar. It is a mixture of many compounds, mostly aromatic hydrocarbons. As a wood preservative, it is primarily used to improve the weathering characteristics of wood, provide protection from insects and fungi, and promote insolubility in water. The primary disadvantages of creosote-treated wood products are color, odor, oily unpaintable surfaces, and tendency to bleed. The railroad industry uses creosote almost exclusively (99.5 percent of the preserved wood total) to treat cross and switch ties. In addition, over 90 percent of all pilings are treated with creosote.

Penta is a crystalline compound dissolved in light petroleum oil. Primarily, these treated products are resistant to insects and fungi and are more paintable than creosote. Sixty-five percent of all utility poles and over 90 percent of all utility pole cross arms are treated with penta. In addition, 25 percent of construction lumber and timber products are treated with penta (Reference 3).


WASH
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NEBR.
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IND.
OHIO
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TENN.
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DEL.
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1
2
3
4
5
6
1 NORTHEAST REGION
2 NORTH CENTRAL REGION
3 SOUTHEAST REGION
4 SOUTH CENTRAL REGION
5 ROCKY MOUNTAIN REGION
6 PACIFIC REGION
TYPE OF PLANT
● PRESSURE
▲ NON-PRESSURE
■ PRESSURE AND NON-PRESSURE

Figure 1. Wood preserving plants in the United States (1976) (Reference 27).

Waterborne preservatives are compounds of arsenic, chromium, copper, zinc, and fluoride. The principal preservatives, as reported by the American Wood Preservers Association (Reference 30) include CCA, fluor-chrome-arsenate-phenol (FCAP), chromated zinc chloride, and acid copper chromate. They differ from creosote and penta in that they are water soluble inorganic substances as opposed to oily, organic substances.

Waterborne preservatives produce a clean, odorless, paintable product. Disadvantages of waterborne preservatives are that the wood must be dried before it is treated rather than using a simultaneous processing step.

Approximately 45 percent of construction lumber is treated with waterborne preservatives. This use represents 83 percent of the total volume of lumber treated with waterborne salts. Other lesser uses include utility poles and fenceposts.

A detailed breakdown of the volume of wood treated as a function of preservatives and product is presented in Table I. Until 1950, the total volume of wood preserved closely followed the volume of creosote used. Since the early 1950's there has been a general downward trend in consumption of products treated with creosote and a corresponding upswing in the use of waterborne and penta preservatives (Reference 30).

By 1960, creosote use had dropped to 73.1 percent of the total preservatives used. In this same time period, penta use increased from 5.4 to 22 percent and waterborne salts from 3.4 to 6.4 percent of the total preservatives used.

Following 1965, there was an increase in total wood preserved but a further decrease in creosote consumption. With the increasing use of the alternative preservatives, creosote was used more exclusively to treat railroad ties, accounting for 70.6 percent of creosote use by 1975. Creosote consumption continues to be clearly aligned with trends in the railroad industry and with the need for products in contact with salt water.

The consumption of creosote, penta, and waterborne salts as a function of time is shown in Figure 2. Penta and waterborne salts are more suitable than creosote in many instances. While neither provides the physical protection of creosote, the appearance of the treated product is often superior. Products treated with penta and waterborne salts are used in home and building construction, agricultural applications, playground equipment, decks, and boardwalks. Waterborne salts are ideal for ground contact use due to their nonvolatility, cleanliness, and lack of odor. Wood treated with waterborne salts has also been successful in replacing concrete used in small building and house foundations.

The projected future use of treated wood is dependent on several factors, including:

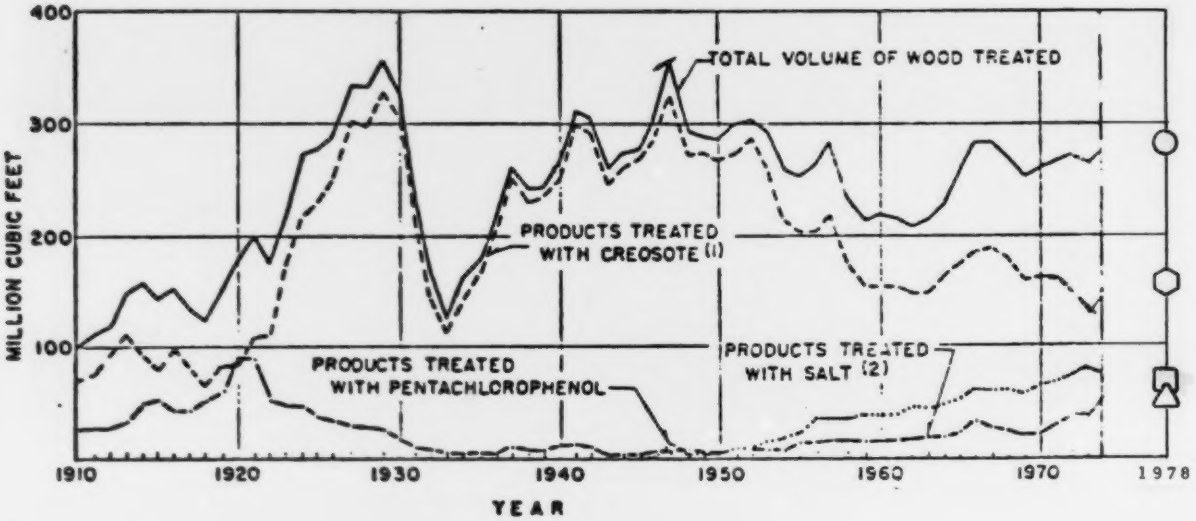
- The availability of suitable poles for use by the utility industry. Alternatives such as steel towers and laying the cable underground may result in reduced penta usage.

TABLE I. VOLUME OF WOOD TREATED IN 1978 BY PRESERVATIVE AND PRODUCT (1,000 FT^3) (Reference 30)

Preservative type	Cross ties	Switch ties	Piling	Poles	Cross arms	Lumber and timbers	Fence-posts	Other	Total
Creosote and creosote-coal tar	93,976	5,152	8,643	17,404	78	9,586	1,607	3,324	139,770
Creosote-petroleum	16,481	1,085	7	0	0	749	138	174	18,634
Creosote-penta	0	0	0	0	4	320	1,180	20	1,524
Petroleum-penta	893	0	297	39,406	423	17,985	5,975	3,313	68,292
Chromated copper arsenate (A, B, C)	347	6	791	4,148	121	48,784	1,986	6,136	62,319
Fluor-chrome-arsenate-phenol	(D)	0	(D)	10	0	240	(D)	(D)	(D)
Chromated zinc chloride	0	(D)	0	0	0	1,507	0	55	1,562
Acid copper chromate	0	0	0	0	0	(D)	0	0	(D)
All other preservatives	28	10	24	858	0	1,622	13	55	2,610
All preservatives	111,725	6,253	9,763	61,826	626	80,793	10,899	13,077	294,711

Note: Components may not add to totals due to rounding.

(D) Data not shown to avoid disclosure of individual company data.



(1) Includes creosote, creosote-coal tar solutions, creosote-petroleum (1924 to 1074), creosote-petroleum-copper-naphthenate (1946-48), zinc creosote (1909-33), and creosote-petroleum-penta solutions (1946 to 1974)

(2) Includes waterborne solutions of zinc chloride, chromated zinc chloride, zinc meta arsenite, ammoniacal copper arsenate, chromated copper arsenate, fluor chrome arsenate phenol, and acid copper chromate

(3) Data from Table I

○ Total preserved wood
⬡ Total creosote (see 1, above)
□ Total penta
△ Total inorganic salts (see 2, above)

Figure 2. Historic trends in forest products treated with various preservatives (Reference 4).

- Creosote use should increase correspondingly to an increase of railroad activity. Tie replacement rate is expected to remain constant into the future at a rate of 22 million/year. The stability of this figure is due to government funding for maintenance, an increase of coal and grain rail transport over trucking, and state-supported maintenance (Reference 5).

- Use of preserved lumber and timber for construction should increase. Homes and buildings using treated wood are resistant to termites and decay. This increase will result in an increase in the use of penta and waterborne salts.

- The increasing costs of oils used as the carrier for penta preservatives may necessitate use of more economically feasible alternatives to preserve wood

- The potential ban of penta, creosote, and the arsenical preservatives may force the use of alternatives to preserved wood

The previous discussion is not intended to project the health and future of the wood treating industry, but to provide the basis for projecting the future multimedia emission factors of pollutants. The emission factors will be impacted most severely by regulation of discharge streams followed by consumer demand for treated wood products. For the purposes of this study, a projection of 0.2 percent/year will be used to describe the growth of the wood treating industry. Within that sector, creosote is projected to decrease at a rate of 1.5 percent/year and penta and waterborne salts will increase at a rate of 6.8 percent/year and 5.8 percent/year, respectively. These projections are based on historical consumption data and do not reflect future regulation of waste streams or preservative use.

4.3 HEALTH AND ENVIRONMENTAL IMPACTS

Preserved wood contains chemicals known to be toxic. Manufacturing processes producing the treated wood generate solid, liquid, and gaseous wastes that can also contain these compounds. Health and environmental impacts of these chemicals have recently been the subject of numerous studies (see Section 8).

Analysis of solid wastes has shown that the hazardous components consist of penta, creosote, and heavy metal salts. Table II shows estimates of solid waste generated by the wood preserving industry. It is estimated that an average total of about 1300 metric tons of solid waste are generated each year of which an average of less than 9 metric tons is hazardous waste. Although the wastes are listed in terms of amounts generated per year, it must be noted that many of the wastes are formed on a periodic basis over as much as 5 years (Reference 6).

Wood preserving wastewaters typically have high phenolic, chemical oxygen demand (COD), oil concentrations, and turbid appearance due to emulsified oils. These wastewaters are acidic, usually having a pH between 4.1 and 6.0 (Reference 6). Typical pollutant concentrations are listed in

TABLE II. POTENTIALLY HAZARDOUS SOLID WASTES FROM THE WOOD PRESERVING INDUSTRY (Reference 6)

Total process solid waste (metric tons/yr)	Total potentially hazardous constituents (metric tons/yr)	Average concentration (mg/kg = ppm)	Toxicity data
Creosote-oil emulsion 230-930	Creosote 1.1-4.6	5,000	Or-1-rat, LD50:725 mg/kg Or-1-dog, LD50:600 mg/kg
Penta-oil emulsion 600[a]	Penta 3.0	5,000	Or-1-human, LD50:29 mg/kg Or-1-rat, LD50:50 mg/kg Suspected carcinogen
WSP residue[b] 27-140	Heavy metal salts[c] 0.27-1.4	10,000	Category I -- suspected carcinogen

[a] Estimated maximum amount

[b] Residues from treatment plants using water-soluble preservatives

[c] Typical components: Copper oxide, chromic acid, arsenic pentoxide or trioxide, chromium trioxide, chromated zinc chloride, acetic acid, boric acid, fluorides

Table III. The quantity of wastewater generated varies widely from plant to plant, ranging from 7500 to 22,700 l/day (2,000 to 60,000 gallons/day) (Reference 7). Factors affecting the amount of wastewater include the preservative used, conditioning technique, and amount and type of wood treated.

Gaseous emissions in the form of dense white vapors are released from the retort when the retort door is opened. These emissions contain organic vapors, steam, and particulate (creosote or oilborne preservative droplets) and are typically emitted at a rate of 1.6 kg/hr (3.6 lb/hr) per retort (Reference 6). Wastewater evaporation ponds also generate some organic vapor emissions. The amounts are described by the test data and evaporation modeling described in Section 6.

The solid and liquid wastes generated by the industry are typically treated by a number of processes. This may include flocculants, phase separation, evaporation, land irrigation, and/or landfilling. Several studies have been conducted to investigate the fate of the toxic components in the environment and determine whether they are degraded by soil microorganisms or sunlight, as well as whether groundwater contamination occurs. Few studies have been conducted to determine the fate or environmental impact of the gaseous emissions (References 11 and 16).

Studies on the effect of soil conditions on penta degradation indicate that biodegradation occurs readily in flooded or anaerobic soils, and that the rate of degradation depends on the soil temperature, soil type, sludge or wastewater application rate, and the quantity of organic matter present in the soil. A study comparing the effects of aerobic versus anaerobic conditions found that, of the 100 ppm penta initially present, only half was present in the anaerobic soil after 10 to 40 days; however, almost all of the pollutant was still present in the aerobic soil after 2 months. In both cases, the soil was maintained at 30°C throughout the study. Another study showed that penta degradation in sterile soils was negligible, suggesting that microbial activity and penta loss are related (References 12, 15, and 21). It has also been shown that the concentration of penta in the wastes strongly affects microbial degradation. There is, however, some disagreement as to the optimal concentration above which the penta is toxic to microbial organisms and degradation ceases (References 15 and 17).

Major issues of concern are the environmental effects of impurities present in commercial grade penta and of breakdown products. These are generally classified as chlorinated dioxins and are the subject of study by many government agencies because of their toxicity both in the natural environment and the work place. Private companies are also active in researching these compounds to provide information for retaining the registration of penta as a wood preservative.

Chlorinated dibenzo-p-dioxins of interest in penta are hexa-, hepta-, and octachloro-dibenzo-p-dioxin. The amount of these impurities present in any sample varies greatly depending on the manufacturer and analytical technique used. These are toxic compounds, and while not as extreme in their toxicity as 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD) (comparable

TABLE III. DATA ON RAW EFFLUENT FROM CREOSOTE AND PENTA PROCESSES (Reference 6)

Waste parameters	Usual range of concentrations[a] (mg/l = ppm)	Average concentration for 24-hour composite samples for five plants
Total phenolic compounds	100 to 350	137[b]
Chemical oxygen demand	3,000 to 60,000	17,890[b]
Biochemical oxygen demand	1,000 to 25,000	8,732[b]
Oil content	80 to 2,000	176[b]
Total solids	2,000 to 20,000	11,000[b]
Total volatile solids	1,000 to 10,000	--
Dissolved solids	1,800 to 18,000	9,000
pH	3.5 to 6.0	5.1[b]

[a] Units of measure are mg/l for all parameters except pH

[b] Each value is of the average of from 125 to 250 separate analyses

to thalidomide but said to be 100,000 to 1 million times more potent), they are cause for concern and candidates for investigation (References 17, 20, and 22).

An in-depth discussion of these compounds, their generation, effects, and degradation is not possible in the scope of this task. The reader is referred to the noted references for a detailed treatment of the subject. In addition, Reference 10 presents a detailed discussion of TCDD, while Reference 23 treats TCDD as well as hexa-, hepta-, and octachloro-dibenzo-p-dioxins.

Considerable evidence exists associating wood preservative contact with adverse health effects, and although the impacts of continued, long-term exposure to low levels of these toxic compounds are still under investigation, there is evidence indicating that they may be mutagenic, teratogenic, and carcinogenic. It is therefore imperative that the fate of these toxic chemicals, their generation, disposal, environmental transport mechanisms, and emission rates, be thoroughly understood. The health impacts that may occur due to exposure to wood preservatives is presented for informational purposes and is not a complete description. Readers are referred to Reference 31 for an in-depth discussion. These impacts, however, have led to more stringent regulation of these wastes that do impact the primary topical areas of this report.

4.4 REGULATION REVIEW

The Federal Water Pollution Control Act (FWPCA) of 1972, as amended by the Clean Water Act (CWA) of 1977, and the Resource Conservation and Recovery Act (RCRA) of 1976 are the two primary federal laws carried out by EPA that regulate the effluent and sludge disposal practices of the wood preserving industry. Overlapping laws administered by EPA are the Clean Air Act (CAA) of 1972, The Federal Insecticide, Fungicide, and Rodentcide Act of 1972, and the Marine Protection, Research, and Sanctuary Act of 1972.

Through regulations under the Clean Water Act, all wood preserving processes, with the exception of steam conditioning, are required to have zero discharge of process wastewater pollutants into navigable waters. During the development of guidelines and standards for this act, EPA reported that 60 percent of operating plants had already implemented practices to eliminate the discharge of pollutants. Presently, plants treating with oily preservatives have generally chosen to meet previously published effluent limitations by discharging pretreated wastewater POTW or by achieving no-discharge status through either soil irrigation or evaporation (Reference 27). The wastewater, generated as a consequence of wood preserving operations, can be reduced to a sludge. RCRA provides for the promulgation of guidelines for collection, transport, separation, recovery, and disposal practices and systems for these sludges.

The details of these acts as applicable to the wood preserving industry are summarized in the following paragraphs.

4.4.1 Clean Water Act Regulations Affecting the Wood Preserving Industry

On January 3, 1974, notice was published in the Federal Register (Vol. 39, No. 938) that EPA, in response to guidelines set forth by the FWPCA of 1972, was proposing effluent limitations guidelines for existing sources in the timber products processing category of point sources. Included in this category were: wood preserving, wood preserving-steam, and wood preserving-boultonizing subcategories. Performance and pretreatment standards for new sources within these subcategories were also proposed by EPA. The Federal Register (Vol. 39, April 18, 1974) established these Final Effluent Limitations Guidelines by amending 40 CFR, Chapter I, Subchapter N, to add a new Part 429. Pretreatment standards were further amended in the Federal Register (Vol. 41, December 9, 1976). Final regulations and standards for the wood preserving industry are contained in Subparts F, G, and H of Part 429, The Timber Products Processing Point Source Category, in Subchapter N (Effluent Guidelines and Standards) of Chapter I in the Code of Federal Regulations.

On June 9, 1976, a consent decree was signed by EPA and the National Resources Defense Council requiring EPA to promulgate revised effluent limitations for 21 point source categories including the wood preserving industry. The proposed effluent guideline modifications for wood preserving were published October 31, 1979 (Reference 27) and are to be finalized in early 1981.

Effluent limitations guidelines are established for steam wood preserving, boultonized wood preserving, all nonpressure preserving processes, and all pressure and nonpressure processes employing waterborne salts where steaming or vapor drying is not the predominant method of conditioning. See Section 5 for a description of these treating processes. Guidelines are established for these processes considering:

- Application of the best practicable control technology currently available
- Best available technology economically achievable
- Pretreatment standards for existing sources
- Standards of performance for new sources
- Pretreatment standards for new sources

A summary of effluent guidelines for the aforementioned categories is shown in Table IV.

TABLE IV. SUMMARY OF CODES OF FEDERAL REGULATIONS FOR THE TIMBER TREATING INDUSTRY (AS OF JULY 1, 1978) (CFR 40)

<table>
<tr><th>Effluent limitations guidelines for</th><th>Effluent limitations guidelines representing the degree of effluent reduction attainable by the application of the best practicable control technology currently available</th><th>Effluent limitations guidelines representing the degree of effluent reduction attainable by the application of the best available technology economically achievable</th><th>Pretreatment standard for existing sources</th><th>Standard of performance for new sources</th><th>Pretreatment standards for new sources</th></tr>
<tr>
<td>Subpart F -- Wood Preserving Subcategory
Section 429.60 Applicability; description of the wood preserving subcategory.
The provisions of this subpart are applicable to discharges and to the introduction of pollutants into treatment works that are publicly owned resulting from all wood preserving processes in which steaming or boultonizing is not the predominant method of conditioning, all nonpressure preserving processes, and all pressure or nonpressure processes employing waterborne salts in which steaming or vapor drying is not the predominant method of conditioning.</td>
<td>No discharge of process wastewater pollutants into navigable waters.</td>
<td>No discharge of process wastewater pollutants into navigable waters.</td>
<td>No discharge of process wastewater pollutants.</td>
<td>No discharge of process wastewater pollutants into navigable waters.</td>
<td>Section 429.66 Pretreatment standards for new sources.
The pretreatment standards for incompatible pollutants under Section 307 (c) of the Act for a source within the wood preserving subcategory, that is a user of a publicly owned treatment works (and which would be a new source subject to Section 306 of the Act if it were to discharge pollutants to the navigable waters), shall be the standard set forth in 40 CFR Part 128, except for Section 128.133. Subject to the provisions of 40 CFR Part 128, process wastewaters from a new source subject to the provisions of this subpart may be introduced into a publicly owned treatment works.</td>
</tr>
<tr>
<td>Subpart G -- Wood Preserving-Steam Subcategory
Section 429.70 Applicability; description of wood preserving-steam subcategory.
The provisions of this subpart are applicable to discharges and to the introduction of pollutants into treatment works that are publicly owned resulting from wood preserving processes that use direct steam impingement on the wood as the method of conditioning wood preserving processes that use vapor drying as a means of conditioning any portion of their stock, discharges that result from direct steam conditioning wood preserving processes that use fluor-chromium-arsenic-phenol treating solution (FCAP), discharges resulting from direct steam conditioning processes and procedures where the same retort is used to treat with both salt-type and oil type preservatives, and discharges from plants that direct steam condition and apply both salt and oil type treatments to the same stock.
(39 FR 13945, Apr. 18, 1974, as amended at 41 FR 53935, Dec. 9, 1976)</td>
<td><table>
<tr><th rowspan="2">Effluent characteristic</th><th colspan="2">Effluent limitations</th></tr>
<tr><th>Maximum for any 1 day</th><th>Average of daily values for 30 consecutive days shall not exceed—</th></tr>
<tr><td></td><td colspan="2">Metric units (kilograms per 1,000 m³ of product)</td></tr>
<tr><td>COD</td><td>1,100</td><td>550</td></tr>
<tr><td>Phenols</td><td>2.18</td><td>0.65</td></tr>
<tr><td>Oil and grease</td><td>24.0</td><td>12.0</td></tr>
<tr><td>pH</td><td colspan="2">Within the range of 6.0 to 9.0</td></tr>
<tr><td></td><td colspan="2">English units (pounds per 1,000 ft³ of product)</td></tr>
<tr><td>COD</td><td>68.5</td><td>34.5</td></tr>
<tr><td>Phenols</td><td>0.14</td><td>0.04</td></tr>
<tr><td>Oil and grease</td><td>1.5</td><td>0.75</td></tr>
<tr><td>pH</td><td colspan="2">Within the range of 6.0 to 9.0</td></tr>
</table></td>
<td><table>
<tr><th rowspan="2">Effluent characteristic</th><th colspan="2">Effluent limitations</th></tr>
<tr><th>Maximum for any 1 day</th><th>Average of daily values for 30 consecutive days shall not exceed—</th></tr>
<tr><td></td><td colspan="2">Metric units (kilograms per 1,000 m³ of product)</td></tr>
<tr><td>COD</td><td>110</td><td>55</td></tr>
<tr><td>Phenols</td><td>0.21</td><td>0.065</td></tr>
<tr><td>Oil and grease</td><td>3.4</td><td>1.1</td></tr>
<tr><td>pH</td><td colspan="2">Within the range of 6.0 to 9.0</td></tr>
<tr><td></td><td colspan="2">English units (pounds per 1,000 ft³ of product)</td></tr>
<tr><td>COD</td><td>6.9</td><td>3.4</td></tr>
<tr><td>Phenols</td><td>0.014</td><td>0.004</td></tr>
<tr><td>Oil and grease</td><td>0.21</td><td>0.07</td></tr>
<tr><td>pH</td><td colspan="2">Within the range of 6.0 to 9.0</td></tr>
</table></td>
<td>Section 429.64 Pretreatment standard for existing sources.
For the purpose of establishing pretreatment standards under Section 307 (b) of the Act for a source within the wood preserving subcategory, the provisions of 40 CFR Part 128 shall not apply. The pretreatment standards for an existing source within the wood preserving subcategory are set forth below.
(a) No pollutant (or pollutant property) introduced into a publicly owned treatment works shall interfere with the operation or performance of the works:
(1) Pollutants that create a fire or explosion hazard in the publicly owned treatment works.
(2) Pollutants that will cause corrosive structural damage to treatment works, but in no case pollutants with a pH lower than 5.0, unless the works is designed to accommodate such pollutants.
(3) Solid or viscous pollutants in amounts that would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works.
(4) Pollutants at either a hydraulic flowrate or pollutants flowrate that is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.</td>
<td><table>
<tr><th rowspan="2">Effluent characteristic</th><th colspan="2">Effluent limitations</th></tr>
<tr><th>Maximum for any 1 day</th><th>Average of daily values for 30 consecutive days shall not exceed—</th></tr>
<tr><td></td><td colspan="2">Metric units (kilograms per 1,000 m³ of product)</td></tr>
<tr><td>COD</td><td>110</td><td>55</td></tr>
<tr><td>Phenols</td><td>0.21</td><td>0.065</td></tr>
<tr><td>Oil and grease</td><td>3.4</td><td>1.1</td></tr>
<tr><td>pH</td><td colspan="2">Within the range of 6.0 to 9.0</td></tr>
<tr><td></td><td colspan="2">English units (pounds per 1,000 ft³ of product)</td></tr>
<tr><td>COD</td><td>6.9</td><td>3.4</td></tr>
<tr><td>Phenols</td><td>0.014</td><td>0.004</td></tr>
<tr><td>Oil and grease</td><td>0.21</td><td>0.07</td></tr>
<tr><td>pH</td><td colspan="2">Within the range of 6.0 to 9.0</td></tr>
</table></td>
<td>429.76 Pretreatment standards for new sources.
The pretreatment standards for incompatible pollutants under Section 307(c) of the Act for a source within the wood preserving-steam subcategory, that is a user of a publicly owned treatment works (and which would be a new source subject to Section 306 of the Act if it were to discharge pollutants to the navigable waters), shall be the standard set forth in 40 CFR Part 128, except for Section 128.133. Subject to the provisions of 40 CFR Part 128, process wastewaters from a new source subject to the provisions of this subpart may be introduced into a publicly owned treatment works.</td>
</tr>
<tr>
<td>Subpart H--Wood Preserving-Boultonizing Subcategory
429.80 Applicability; description of the wood preserving-boultonizing subcategory.
The provisions of this subpart are applicable to discharges and to the introduction of pollutants into treatment works that are publicly owned resulting from wood preserving processes that use the boultonizing process as the method of conditioning.
(39 FR 13945, Apr. 18, 1974, as amended at 41 FR 53935, Dec. 9, 1976)</td>
<td>No discharge of process wastewater pollutants into navigable waters.</td>
<td>No discharge of process wastewater pollutants into navigable waters.</td>
<td><table>
<tr><th rowspan="2">Pollutant or pollutant property</th><th colspan="2">Pretreatment standard</th></tr>
<tr><th>Maximum for any 1 day (milligrams per liter)</th><th>Maximum for any 1 day [illegible]</th></tr>
<tr><td>Oil and grease</td><td>100</td><td>20.1</td></tr>
<tr><td>Copper</td><td>5</td><td>1.0</td></tr>
<tr><td>Chromium</td><td>4</td><td>0.8</td></tr>
<tr><td>Arsenic</td><td>4</td><td>0.8</td></tr>
</table></td>
<td>No discharge of process wastewater pollutants into navigable waters.</td>
<td>Section 429.86 Pretreatment standards for new sources.
The pretreatment standards for incompatible pollutants under Section 307(c) of the Act for a source within the wood preserving-steam subcategory, that is a user of a publicly owned treatment works (and which would be a new source subject to Section 306 of the Act if it were to discharge pollutants to the navigable waters), shall be the standard set forth in 40 CFR Part 128, except for Section 128.133. Subject to the provisions of 40 CFR Part 128, process wastewaters from a new source subject to the provisions of this subpart may be introduced into a publicly owned treatment works.</td>
</tr>
</table>

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The FWPCA amendments (called the Clean Water Act) outlined a list of toxic pollutants to be regulated (see Table V). The Clean Water Act has also required EPA to define a list of conventional and nonconventional pollutants and set appropriate effluent emissions guidelines. Section 42 of the 1977 Clean Water Act amends Section 301(b) of the FWPCA and requires dischargers of conventional pollutants to install the best available pollutant control technology by July 1, 1984. Nonconventional pollutants are expected to include those substances that are not conventional pollutants but cannot be readily classified as toxic. Section 42 of the Clean Water Act requires best practicable effluent controls on nonconventional pollutants by July 1, 1984, or, if earlier, within 3 years after publication of effluent limitations. The final compliance date established in Section 42 is July 1, 1987. The compliance date for toxic pollution controls using the best available technology economically achievable is July 1, 1984. EPA is authorized to add to or subtract from the toxins listed in Table V. Additional toxins must achieve best available technology standards within 3 years after EPA issues effluent limitations.

4.4.2 The Resource Conservation and Recovery Act of 1976 (RCRA)

As congress stated in Section 1002 (b)(3) of the RCRA: "As a result of the Clean Air Act, the Water Pollution Control Act, and other federal and state laws respecting public health and the environment, greater amounts of solid waste (in the form of sludge and other pollution treatment residues) have been created. Similarly, inadequate and environmentally unsound practices for the disposal or use of solid waste have created greater amounts of air and water pollution and other problems for the environment and for health."

Final guidelines and regulations have been established by EPA as outlined in RCRA. Guidelines and regulations and identification and listing procedures were promulgated on Monday, May 19, 1980, and published in the Federal Register (Vol. 45, No. 98). This regulation outlines two sets of requirements: one establishes normal conduct for federal and state agencies in implementing the program, and the second establishes minimum normal conduct for those who generate, transport, treat, store, and dispose of hazardous waste.

EPA has set forth the following characteristics to define hazardous wastes: ignitability, corrosivity, reactivity, and toxicity. As outlined in the Federal Register, a waste is identified as hazardous either because it exhibits one of these characteristics, or because it appears on the list of hazardous wastes. EPA has chosen to emphasize waste streams rather than specific hazardous substances wherever possible because industrial wastes tend to be complex mixtures containing many different components, only some of which may exhibit hazardous characteristics.

The wood preserving industry has been impacted by RCRA in that the "bottom sediment sludge from the treatment of wastewaters from wood preserving processes that use creosote and/or pentachlorophenol" has been

TABLE V. 129 PRIORITY POLLUTANTS TO BE REGULATED BY THE FEDERAL WATER POLLUTION CONTROL ACT (Reference 14)

Acenaphthene
Acrolein
Acrylonitrile
Aldrin/Dieldrin
Antimony and compounds[a]
Arsenic and compounds
Asbestos
Benzene
Benzidine
Beryllium and compounds
Cadmium and compounds
Carbon tetrachloride
Chlordane (technical mixture and metabolites)
Chlorinated benzenes (other than dichlorobenzenes)
Chlorinated ethanes (including 1,2-dichloroethane, 1,1,1-trichloroethane, and hexachloroethane)
Chloroalkyl ethers (chloromethyl, chloroethyl, and mixed ethers)
Chlorinated naphthalene
Chlorinated phenols (other than those listed elsewhere; (includes trichlorophenols and chlorinated cresols)
Chloroform
2-Chlorophenol
Chromium and compounds
Copper and compounds
Cyanides
DDT and metabolites
Dichlorobenzenes (1,2-,1,3-, and 1,4-dichlorobenzenes)
Dichlorobenzidine
Dichloroethylenes (1,1- and 1,2-dichloroethylene)
2,4-dichlorophenol
Dichloropropane and dichloropropene
2,4-dimethylphenol
Dinitrotoluene
Diphenylhydrazine
Endosulfant and metabolites
Endrin and metabolites
Ethylbenzene
Fluoranthene
Haloethers (other than those listed elsewhere, includes chlorophenyphenyl ethers, bromophenylphenyl ether, bis(dischloroisopropyl) ether, bis-(chloroethoxy) methane and polychlorinated diphenyl ethers)
Halomethanes (other than those listed elsewhere; includes methylene chlorid methylchloride, methylbromide, bromoform, dichlorobromomethane, trichlorofluoromethane, dichlorodifluoromethane)
Heptachlor and metabolites
Hexachlorobutadiene
Hexachlorocyclohexane (all isomers)
Hexachlorocyclopentadiene
Isophorone
Lead and compounds
Mercury and compounds
Naphthalene
Nickel and compounds
Nitrobenzene
Nitrophenols (including 2,4-dinitrophenol, dinitrocresol)
Nitrosamines
Pentachlorophenol
Phenol
Phthalate esters
Polychlorinated biphenyls (PCB's)
Polynuclear aromatic hydrocarbons (including benzanthracenes, benzopyrenes, benzofluoranthene, chrysenes, dibenzanthracenes, and indenopyrenes)
Selenium and compounds
Silver and compounds
2,3,7,8 - Tetrachlorodibenzo-p-dioxin
Tetrachloroethylene
Thallium and compounds
Toluene
Toxaphene
Trichloroethylene
Vinyl chloride
Zinc and compounds

---

[a] The term "compounds" shall include organic and inorganic compounds.

listed in Subpart D -- Lists of Hazardous Wastes -- Section 261.32 -- Hazardous waste from specific sources, and is therefore governed by the act.

Wastes defined as hazardous can be disposed of, treated, or stored at the place of generation or at an offsite facility, only in accordance with federal standards published under Subtitle C, or after states have assumed the programs, in accordance with those state standards. Under Subtitle C are the following subparts:

Subpart A -- Section 3001 -- Identification and Listing of Hazardous Waste

Subpart B -- Section 3002 -- Standards Applicable to Generators of Hazardous Waste

Subpart C -- Section 3003 -- Standards Applicable to Transporters of Hazardous Waste

Subpart D -- Section 3004 -- Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

Subpart E -- Section 3005 -- Permits for Treatment, Storage, and Disposal of Hazardous Waste

Subpart F -- Section 3006 -- Guidelines for Authorized State Hazardous Waste Programs

Subpart G -- Section 3010 -- Preliminary Notification of Hazardous Waste Activities

A summary of these sections and provisions for hazardous waste regulation and land disposal controls under the RCRA of 1976 is contained in Table VI.

The Clean Water Act of 1977 and RCRA of 1976 overlap with regard to the treatment of sludge. Section 405(d) of the Federal Water Pollution Act, as amended by the Clean Water Act of 1977 (Pub. L. 95-217) requires EPA to develop regulations providing guidelines for the disposal and utilization of sludge. These criteria are proposed to partially fulfill EPA's responsibility under Section 405(d), with respect to the land disposal and land spreading of sludge. The Office of Solid Wastes personnel are preparing best engineering judgment manuals to cover the same activities.

Finally, a list was published, in the Federal Register (Vol. 43, Monday, December 18, 1978), of permissible exposure levels for airborne contaminants taken from Occupational Safety and Health Administration (OSHA) regulations. A number of the common compounds found in wood preserving chemicals are presented in Table VII.

TABLE VI. SUMMARY OF RCRA HAZARDOUS WASTE REGULATIONS AND LAND DISPOSAL (Reference 13)

PROVISIONS FOR HAZARDOUS WASTE REGULATION AND LAND DISPOSAL CONTROLS UNDER THE RESOURCE CONSERVATION AND RECOVERY ACT OF 1976

Hazardous Waste Regulation

Subtitle C of RCRA contains the hazardous waste authorities, which include the development of criteria for determining which wastes are hazardous, institution of a manifest system to track these wastes from point of generation to point of disposal, and organization of a permit system, based on standards, for hazardous waste treatment, storage and disposal facilities.

Under these controls, each generator will determine whether his waste is hazardous according to the criteria, identification methods, and tests specified by EPA. If it is, he must either obtain a permit to manage it on his property, or ship it to a permitted offsite treatment, storage, or disposal facility. In the latter case, a multicopy manifest containing basic information about the waste must accompany the shipment. In either case, all treatment, storage, and disposal operations must meet the minimum standards developed.

The standards and regulations thus lay the framework for a national system to control hazardous wastes. However, Congress was clear in its intent that the states implement the hazardous waste regulatory system as a part of comprehensive solid waste management programs. The law directed EPA to develop within 18 months the guidelines by which such authority can be granted. EPA must grant authorization to a state unless EPA finds that the proposed program does not meet the requirements established by RCRA.

Some key aspects of the regulatory program are noted as follows:

- Defining a Hazardous Waste. Section 3001 of RCRA mandates the promulgation of regulations identifying and listing hazardous wastes
- Standards for Generators of Hazardous Waste. Section 3002 requires standards for generators of hazardous waste respecting: recordkeeping, labeling of containers, use of appropriate containers, furnishing of information on waste composition, and submission of reports to EPA or authorized state agency. Since many of the standard impact transportation (labeling, containers, manifests, furnishing of information), EPA is coordinating the development of Section 3002 regulations with the Office of Hazardous Materials Operation, Department of Transportation.

(continued)

TABLE VI. (concluded)

- Standards for Transporters of Hazardous Waste. Section 3003 requires standards for transporters covering as a minimum recordkeeping, labeling, compliance with the manifest system, and transportation of all hazardous wastes only to the waste management facility which the shipper declares on the manifest form to be a permitted facility.

- Regulations for Treatment, Storage, and Disposal. Section 3004 mandates the development of performance regulations for hazardous waste treatment, storage, and disposal facilities; such regulations include requirements respecting recordkeeping, reporting, monitoring, design, construction, training, and ownership.

- Permit System Development. Under Section 3005, regulations are to be developed requiring each person owning or operating a facility for the treatment, storage, or disposal of hazardous waste to obtain and comply with a permit. The permit system must provide a mechanism to assure uniform control by states or EPA over hazardous waste management facilities, including maintenance of data for compliance monitoring and enforcement.

- Notification. Section 3010(a) requires that all persons generating or transporting hazardous wastes or operating facilities for treatment, storage, or disposal of hazardous wastes notify the EPA Administrator (or authorized state programs) within 90 days of promulgation of the definition of hazardous wastes under Section 3001. Notification must consist of the name and location of the person conducting hazardous waste activities, the type(s) of activities, and a description of the waste handled.

- State Implementation. Section 3006 allows EPA to authorize states to conduct hazardous waste regulatory programs in lieu of the federal program. The Act recognizes that few of the states will be prepared to administer and enforce a program as comprehensive as that mandated under Subtitle C; consequently it provides for "interim authorization." The only criterion for "interim authorization" is that the proposed state program be "substantially equivalent" to the federal program. The intent of this provision is clearly that as many states as possible be authorized and that EPA administer and enforce Subtitle C in the fewest possible states. The Act requires EPA to promulgate guidelines for state programs under Section 3006(a).

TABLE VII. PERMISSIBLE EXPOSURE LEVELS FOR SELECTED AIRBORNE CONTAMINANTS

Parameter	Maximum Level
Arsenic	0.05
Flouride	1.4-2.4
Lead	0.05
Mercury	0.002
Chloride	250
Copper	1

Substance	ppm	mg/M
Aniline -- skin	5	19
p-Benzoquinone,	0.1	0.4
Benzyl chloride	--	5
Biphenyl,	0.2	1
p-tert-Butyltoluene	10	60
Carbon black	--	3.5
Chlorinated camphere -- skin	--	0.5
Chlorinated diphenyl oxide	--	0.5
Chlorobenzene (monochlorobenzene)	75f	350
Chlorodiphenyl (42 percent chlorine) -- skin	--	1
Coal tar pitch volatiles (benzene soluble fraction) anthracene, BaP, phenanthrene, acridine, chrysene, pyrene	--	0.2
Cresol (all isomers) -- skin	5	22
Cumene -- skin	50	345
Dimethylbenzene	100	435
Dinitrobenzene (all isomers) -- skin	--	1
Dinitro-o-cresol -- skin	--	0.2
Dinitrotoluene -- skin	--	1.5
Dioxane (diethylene dioxide) -- skin	100	360
Diphenyl	0.2	1
Ethyl benzene	100	435
Fluoride (as F)	--	2.5
Fluorine	0.1	0.2
Hydroquinone	--	2
Lead arsenate	--	0.15
Mesityl oxide	25	100
O methyl styrene	100	480
Naphtha (Coaltar)	100	400
Naphthalene	10	50
p-Nitroaniline -- skin	1	6

(continued)

TABLE VII. (concluded)

Substance	ppm	mg/M
p-Nitrochlorobenzene -- skin	--	1
Nitrotoluene -- skin	5	20
Octachloronaphthalene -- skin	--	0.1
Pentachloronaphthalene -- skin	--	0.5
Pentachlorophenol -- skin	--	0.5
Phenol -- skin	5	19
p-Phenylene diamine -- skin	--	0.1
o-Toluidine -- skin	5	22
Trichloronaphthalene -- skin	--	--
2,4,6-Trinitrophenol	--	--
Vinyl benzene	--	--
Vinyl toluene	100	480
Xylene (xylol)	100	435
Xylidine -- skin	5	25

4.4.3 Future Regulations

In the Federal Register (Vol. 43, Wednesday, October 18, 1978), EPA has published notices of rebuttable presumption against registration (RPAR) on inorganic arsenic, penta, coal tar, creosote, and coal tar neutral oil. A notice of RPAR is issued when the evidence related to risk meets the criteria set forth in 40 CFR 162.11 (a)(3). It is emphasized that a notice of RPAR against registration and continued registration of a pesticide is not a notice of intent to cancel the registration of a pesticide, and may or may not lead to cancellation. The notice of intent to cancel is issued only after the risks and benefits of a pesticide are carefully considered, and it is determined that the pesticide may generally cause unreasonable adverse effects to the environment. Present RPAR activities are to be reported in a position document in 1981 (see Section 8). At present, there are no ideal substitutes for these compounds available for the wood preserving industry.

Considering the current wood preserving waste management methods, it is reasonable to assume that the primary area of concern regarding future environmental regulations will be the disposal and handling of solid wastes (sludges) and air emissions as a result of these processes. Since sludges generated by the wood preserving industry have been listed as hazardous wastes, as outlined by RCRA, several criteria will need to be met by the industry for disposal, transportation and handling, recordkeeping, reporting systems, shipping manifests, and possibly containerization and labeling.

Open burning of industrial wastes (sludges) has been prohibited by RCRA. The air criterion of this act also calls for the control of harmful waste emissions by evaporation and sublimitation to protect public health and welfare. At this time, EPA is requesting comments on the advisability of including specific emission or air quality limits based on modification or extrapolation of OSHA air quality standards.

4.4.4 State and Local Regulations

RCRA (Section 3006) provides authority for state management of hazardous waste programs. According to RCRA regulations, states must initiate programs equivalent and consistent with federal programs. Therefore, state legislation will not be less complex than RCRA regulations. It is conceivable that some states will promulgate more stringent regulations than the federal program.

In relation to local statutes, there are regulations pertaining to hazardous wastes. However, each state or local statute must be altered to agree with new RCRA regulations. At the local level, responsibilities for hazardous waste regulations include: permitting, collection, storage, and disposal operations. More specific local hazardous waste statutes that exist today have been enacted in response to previous or potential public health or environmental incidents resulting from improper handling or disposal of hazardous substances.

SECTION 5

TREATMENT PROCESS DESCRIPTIONS AND WASTES

The treatment of wood with preservatives requires impregnation of the wood with foreign materials designed to protect it from attack by insects, fungi, weather, or fire. The processing steps include wood preparation (debarking, shaping, drying) and preservative application.

This discussion describes the wood preserving processing steps and process emissions, delineates those treatment processes that generate wastewater requiring disposal, and quantifies the generation rate of the wastewater. This information, coupled with the projected industry growth and wastewater treatment procedures, will be the basis for projecting emission factors for the preservatives and treatment processes of interest.

5.1 WOOD CONDITIONING PROCESSES

Before wood is treated with a preservative, the bark is removed and the wood is shaped or incised as necessary. Also, pretreatment drying and conditioning processes may be employed to dry the wood and render it more penetrable to preservatives. Figure 3 shows the various processing steps that can be conducted at a typical wood preserving plant using pressure treating.

Freshly cut and debarked sapwood has a water content of 50 to 70 percent of its wet weight. To permit maximum penetration of preservative, some of this water must be removed. Several different pretreatment drying techniques are used:

- Air seasoning -- Wood is stacked and allowed to dry naturally. This process typically takes from 1 to 12 months and requires large areas of open land.

- Tunnel drying -- Wood is slowly drawn on carts from the cold end to the heated end of an elongated building (tunnel). This tunnel is heated by hot air forced horizontally through the tunnel. Air temperatures are controlled to maintain the temperature gradient. Drying time takes up to 2 weeks. The advantages of this process are that it can be automated and continuous.

- Kiln drying -- This is a batch process for drying timber or poles. The wood is placed in a kiln with heated air. The retention time (from 1 to many hours or days) and kiln temperature are varied according to the size and species of wood being dried.

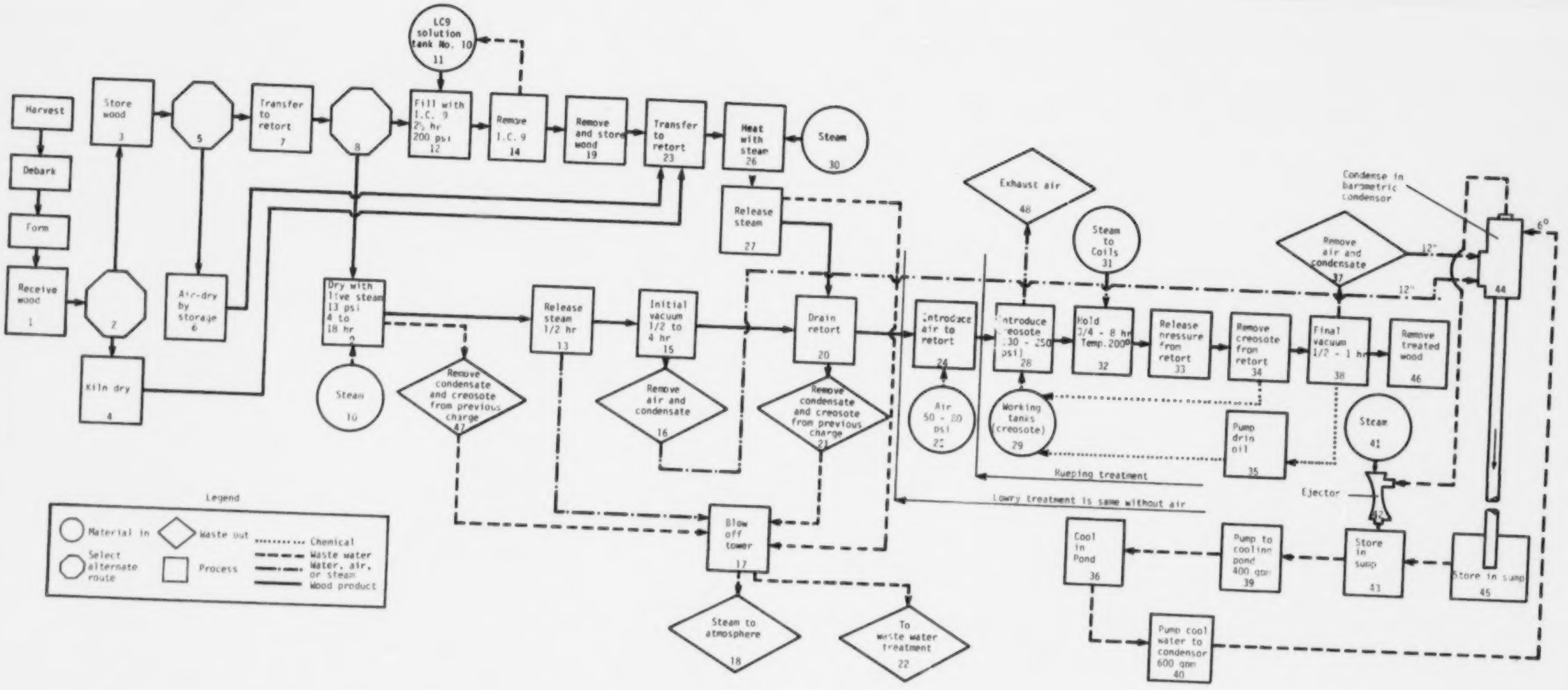

Harvest
Debark
Form
Receive wood 1
2
Store wood 3
Kiln dry 4
5
Air-dry by storage 6
Transfer to retort 7
8
Dry with live steam 13 psi 4 to 18 hr 9
Steam 10
LC9 solution tank No. 10 11
Fill with I.C. 9 2½ hr 200 psi 12
Remove I.C. 9 14
Remove and store wood 19
Transfer to retort 23
Heat with steam 26
Steam 30
Release steam 27
Remove condensate and creosote from previous charge 47
Release steam 1/2 hr 13
Initial vacuum 1/2 to 4 hr 15
Remove air and condensate 16
Drain retort 20
Remove condensate and creosote from previous charge 21
Blow off tower 17
Steam to atmosphere 18
To waste water treatment 22
Introduce air to retort 24
Air 50 - 80 psi 25
Exhaust air 48
Introduce creosote 130 - 250 psi) 28
Working tanks (creosote) 29
Steam to Coils 31
Hold 3/4 - 8 hr Temp. 200°
32
Release pressure from retort 33
Remove creosote from retort 34
Pump drip oil 35
Final vacuum 1/2 - 1 hr 38
Remove treated wood 46
Remove air and condensate 37
12"
12"
Condense in barometric condensor
44
6°
Steam 41
Ejector
42
Store in sump 43
Store in sump 45
Pump to cooling pond 400 gpm 39
Cool in Pond 36
Pump cool water to condensor 600 gpm 40
Rueping treatment
Lowry treatment is same without air
Legend
Material in
Waste out
Select alternate route
Process
Chemical
Waste water
Water, air, or steam
Wood product

Figure 3. Process flow diagram for a typical wood preserving plant using pressure treating (Reference 26).

Several techniques are used that combine wood drying process with wood conditioning and preservative application:

- Steam conditioning -- This process is used both to remove excess moisture from the wood and to render the wood more penetrable to preservatives by softening the wood fibers and dissolving the sap, resins, and bonding materials. Wood is placed in the cylinder and subjected to steam and pressure from 1 to 20 hours. Two different steaming techniques may be used (Figures 4 and 5). Open steaming uses live steam from the boiler to impinge directly on the wood. Steam condensate, which contains preservatives from the previous treating cycle, exits through steam traps, passes through condensers, and then goes on to an oil-water separator. During closed steaming, water from a reservoir is pumped to the retort in sufficient quantities to cover steam coils located at the bottom. Steam from the boiler is passed through the heat exchange coils thereby generating the steam from the surrounding water. This steam also vaporizes the water contained in the wood and conditions the wood. The latter technique results in a much lower volume of wastewater, since the boiler steam can be recycled and is not contaminated with wood resins or preservative in the retort. The condensed water passes through an oil-water separator and is then returned to the reservoir. A blowdown stream from the reservoir controls the volume of foreign material in the reservoir water. The blowdown stream is treated and disposed of (References 25 and 26).

  The steaming time depends on both the size of the wood piece and the steam temperature (typically between 104^o and 118^oC). After steaming, the steam is vented to the atmosphere and a vacuum of at least 0.76 kg/cm^2 is applied to the retort. The maximum amount of water removed by this process is 64 to 80 kg/m^3 of wood (Reference 25).

  Modified closed steaming is a variation of the steam conditioning system as shown in Figure 6. Live steam from the boiler is injected into the retort until the steam heating coils are covered with condensate. At that time, open steaming is terminated and the boiler steam is passed through the heat exchange system (References 25 and 26).

- Vapor drying -- This process employs a high boiling point organic solvent such as naptha to evaporate moisture from the wood. Green timbers are placed in a retort and subjected to organic chemical vapors. These vapors condense on the wood surface transferring the heat of vaporization to the wood, causing the moisture in the wood to vaporize. Mixed organic and water vapors are condensed and separated in a condenser. Recovered solvent is recycled to the retort and wastewaters are sent to wastewater treatment facilities (Figure 7).

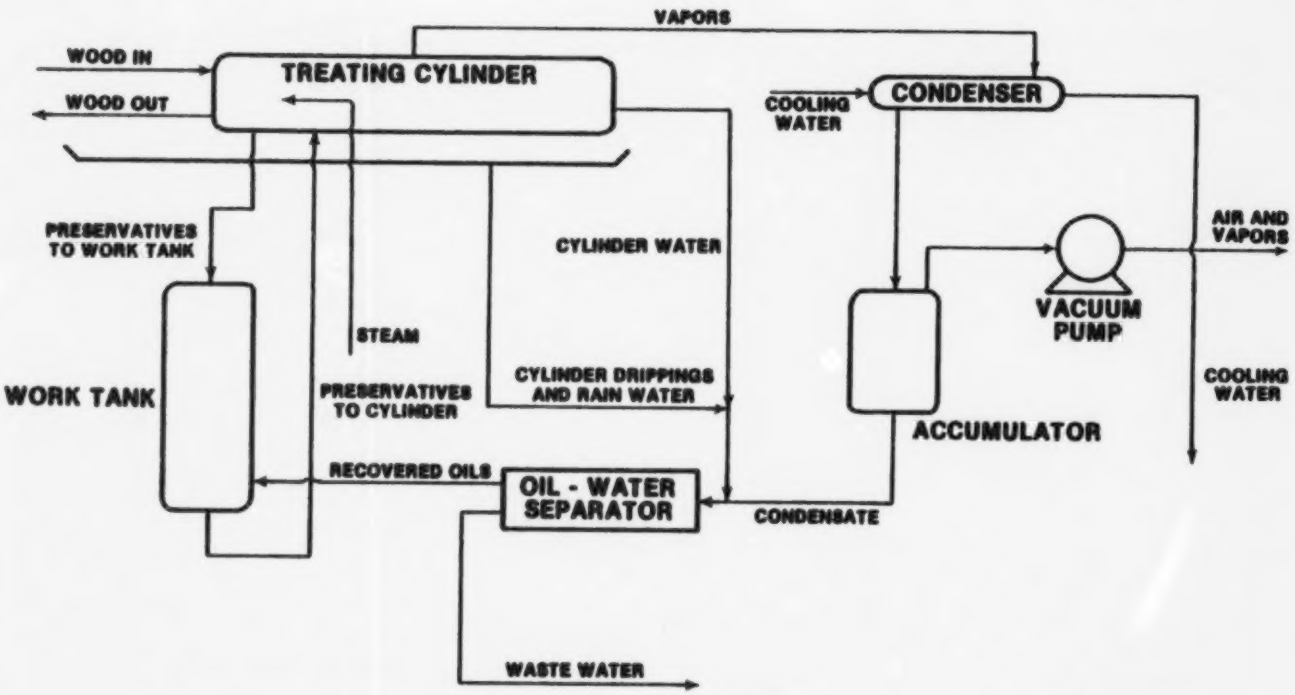

VAPORS
WOOD IN
TREATING CYLINDER
WOOD OUT
COOLING WATER
CONDENSER
PRESERVATIVES TO WORK TANK
CYLINDER WATER
AIR AND VAPORS
VACUUM PUMP
STEAM
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
COOLING WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

Figure 4. Open steaming process (Reference 27).

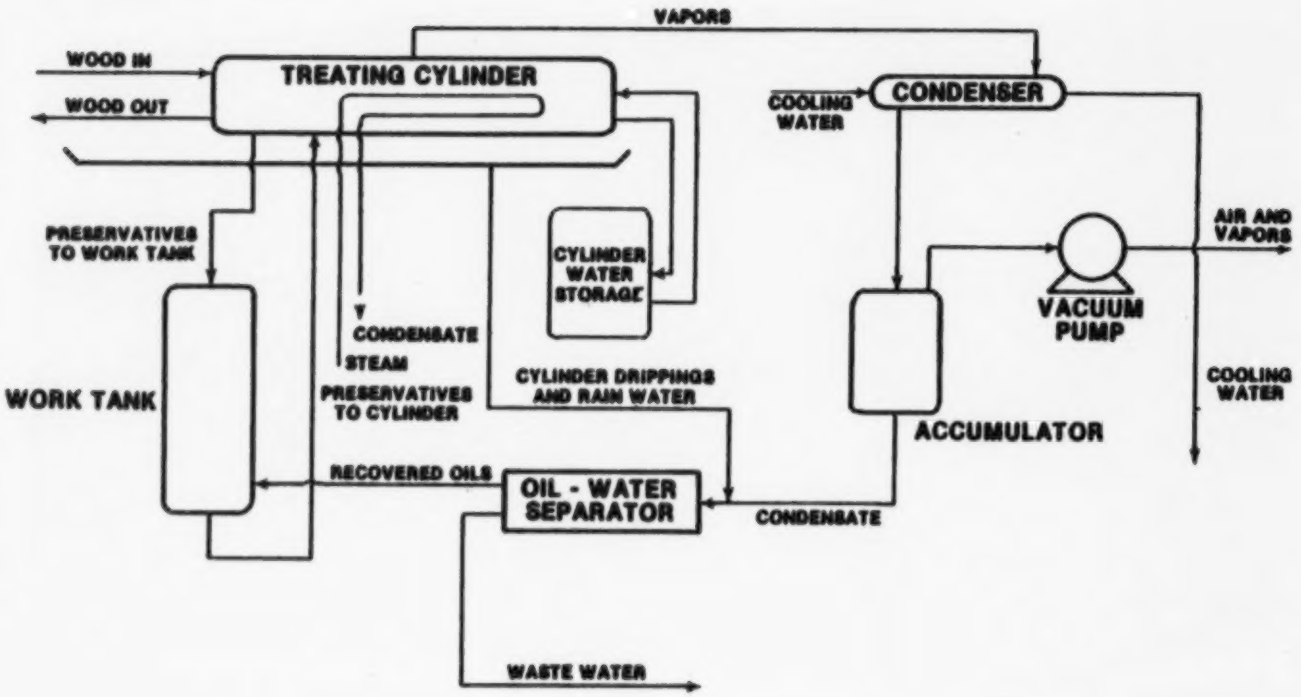

VAPORS
WOOD IN
TREATING CYLINDER
WOOD OUT
COOLING WATER
CONDENSER
PRESERVATIVES TO WORK TANK
CYLINDER WATER STORAGE
AIR AND VAPORS
VACUUM PUMP
CONDENSATE
STEAM
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
COOLING WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

Figure 5. Closed steaming process (Reference 27).

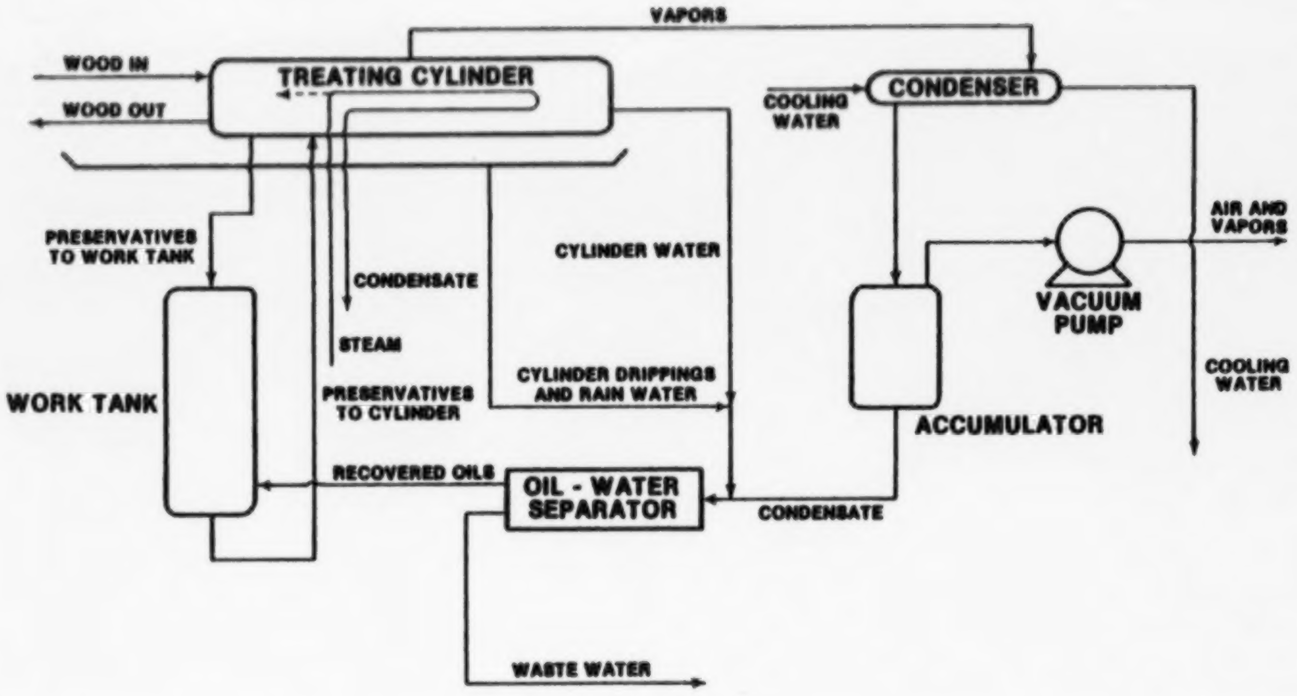

VAPORS
WOOD IN
TREATING CYLINDER
WOOD OUT
COOLING WATER
CONDENSER
PRESERVATIVES TO WORK TANK
CYLINDER WATER
AIR AND VAPORS
CONDENSATE
VACUUM PUMP
STEAM
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
COOLING WATER
ACCUMULATOR
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

Figure 6. Modified steaming process (Reference 27).

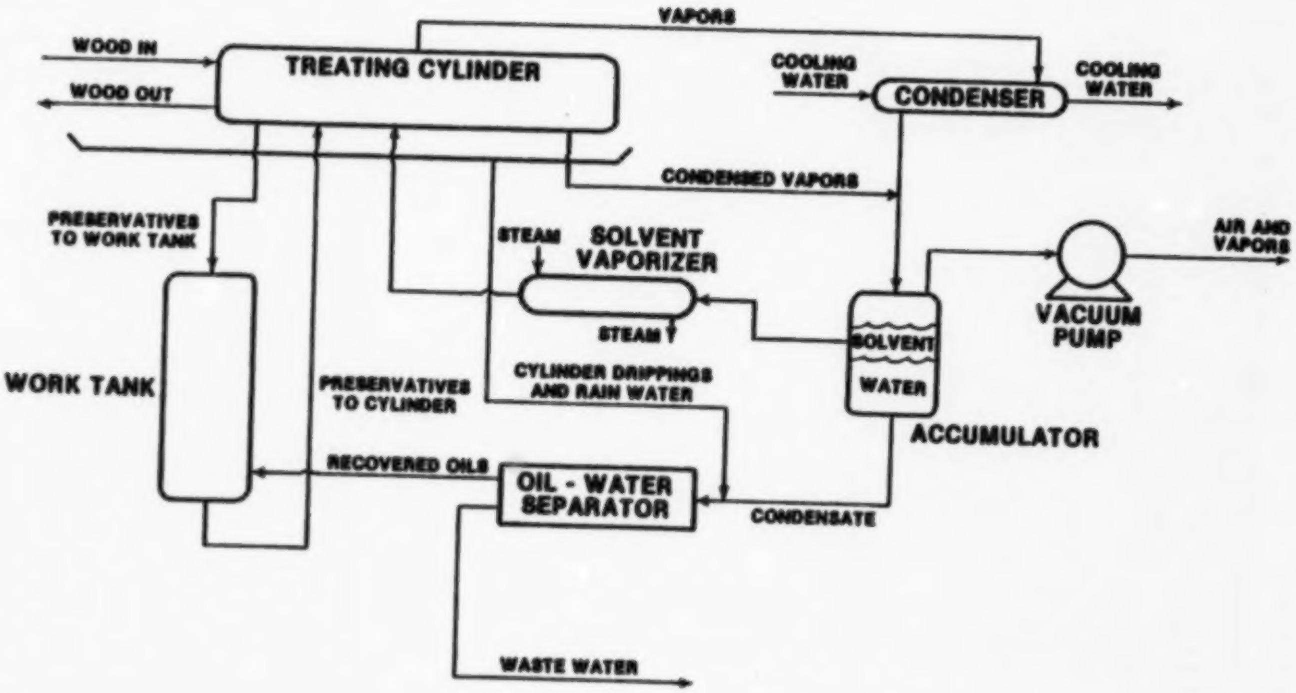

WOOD IN
WOOD OUT
TREATING CYLINDER
VAPORS
COOLING WATER
CONDENSER
COOLING WATER
CONDENSED VAPORS
PRESERVATIVES TO WORK TANK
STEAM
SOLVENT VAPORIZER
STEAM
AIR AND VAPORS
VACUUM PUMP
SOLVENT
WATER
ACCUMULATOR
WORK TANK
PRESERVATIVES TO CYLINDER
CYLINDER DRIPPINGS AND RAIN WATER
RECOVERED OILS
OIL - WATER SEPARATOR
CONDENSATE
WASTE WATER

Figure 7. Vapor conditioning process (Reference 27).

- Boultonizing -- This technique is applicable only when the wood is to be treated with oilborne preservatives such as creosote or penta, and is typically used on Douglas fir or oak. The wood is placed in a cylinder, the cylinder is filled with preservative and heated to 82° to 99°C. A vacuum is applied lowering the boiling point of the water in the wood, causing it to vaporize. The total amount of water removed varies from 32 to 198 kg/m^3. The vapors generated during this process are removed by the vacuum pump and condensed to form an oily wastewater. The condensate, along with contaminated rainwater from the cylinder platform impoundment area and cylinder drippings, are sent to an oil-water separator. A flow diagram of this process is given in Figure 8.

5.2 PRESERVATIVE APPLICATION PROCESSES

After the wood has been dried and conditioned, it is ready for treatment with preservative using either pressure or nonpressure techniques. Pressure techniques, where the timber is placed in a closed vessel under high pressure, allow deeper penetration of the preservative and therefore better protection of the wood. Nonpressure techniques are used when only minimal treatment is necessary, including brush or spray-on treatment, and soaking in hot or cold preservative.

This report will focus on those processes that generate wastewater streams containing organic pollutants. Processes applying waterborne preservatives will no longer be discussed because they are inorganic in composition and do not generate continuous or semicontinuous wastewater streams. (This precludes insoluble contaminants in the preservative.) Nonpressure treatment will also be excluded because preservative application by soaking does not result in process wastewater streams.

Pressure processes, as shown in Figure 9, require the application of pressure or vacuum, either for preservative application or combinations of drying and preservative application. These activities result in the generation of steam (due to the pressure/temperature/vacuum operations) and the stripping of organic constituents from the treating vessels. This vapor stream ultimately becomes a waste stream requiring disposal. The following discussion describes pressure treating techniques and emission sources.

Two types of pressure processes are typically employed: the full cell process, leaving the wood cells full of preservative, and the empty cell (Lowry and Rueping) process, coating the wood cells with preservative. In the full cell process, wood is placed in a retort and a vacuum is applied so that as much air as possible is removed from the wood cells. The retort is then filled with preservative without admitting air. Pressure is applied along with steam heat until the desired degree of chemical penetration is obtained. A final vacuum may be applied to speed removal of excess dripping preservative from the wood. This process is typically employed on wood to be used in marine or other applications, where maximum protection is required.

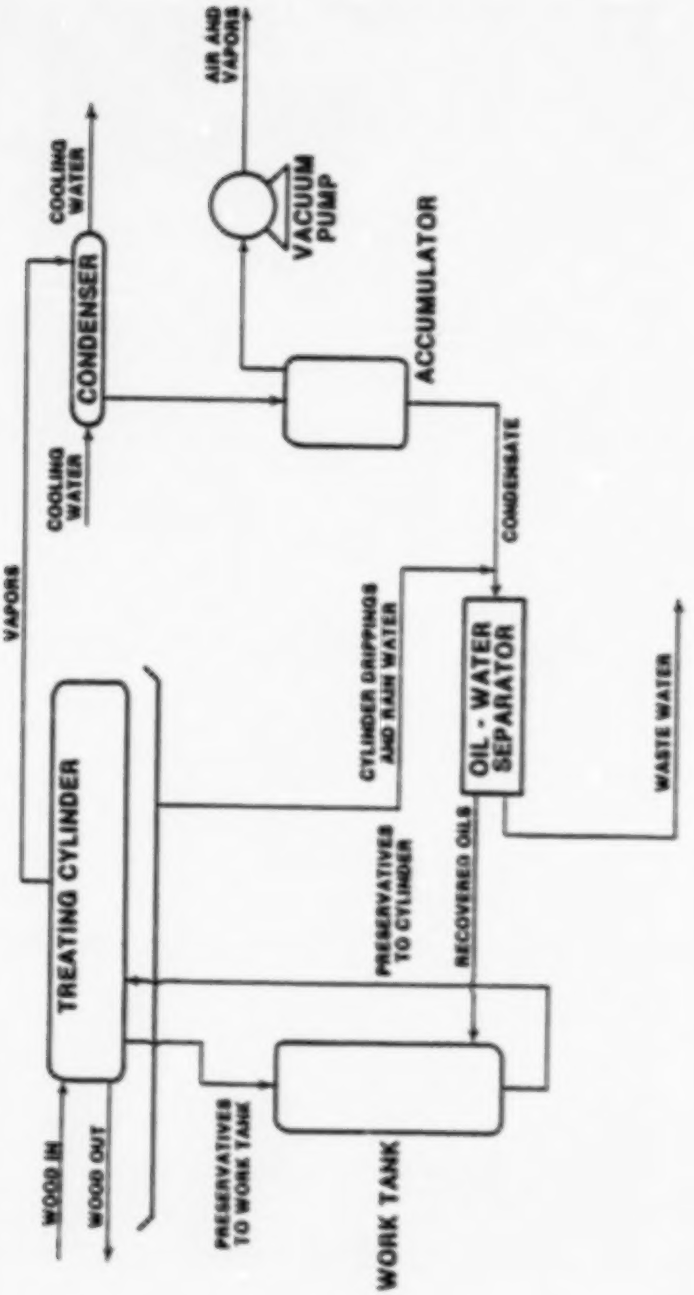

WOOD IN
WOOD OUT
TREATING CYLINDER
VAPORS
COOLING WATER
CONDENSER
COOLING WATER
ACCUMULATOR
VACUUM PUMP
AIR AND VAPORS
CONDENSATE
CYLINDER DRIPPINGS AND RAIN WATER
OIL - WATER SEPARATOR
WASTE WATER
RECOVERED OILS
PRESERVATIVES TO CYLINDER
PRESERVATIVES TO WORK TANK
WORK TANK

Figure 8. Boulton Conditioning Process (Reference 27).

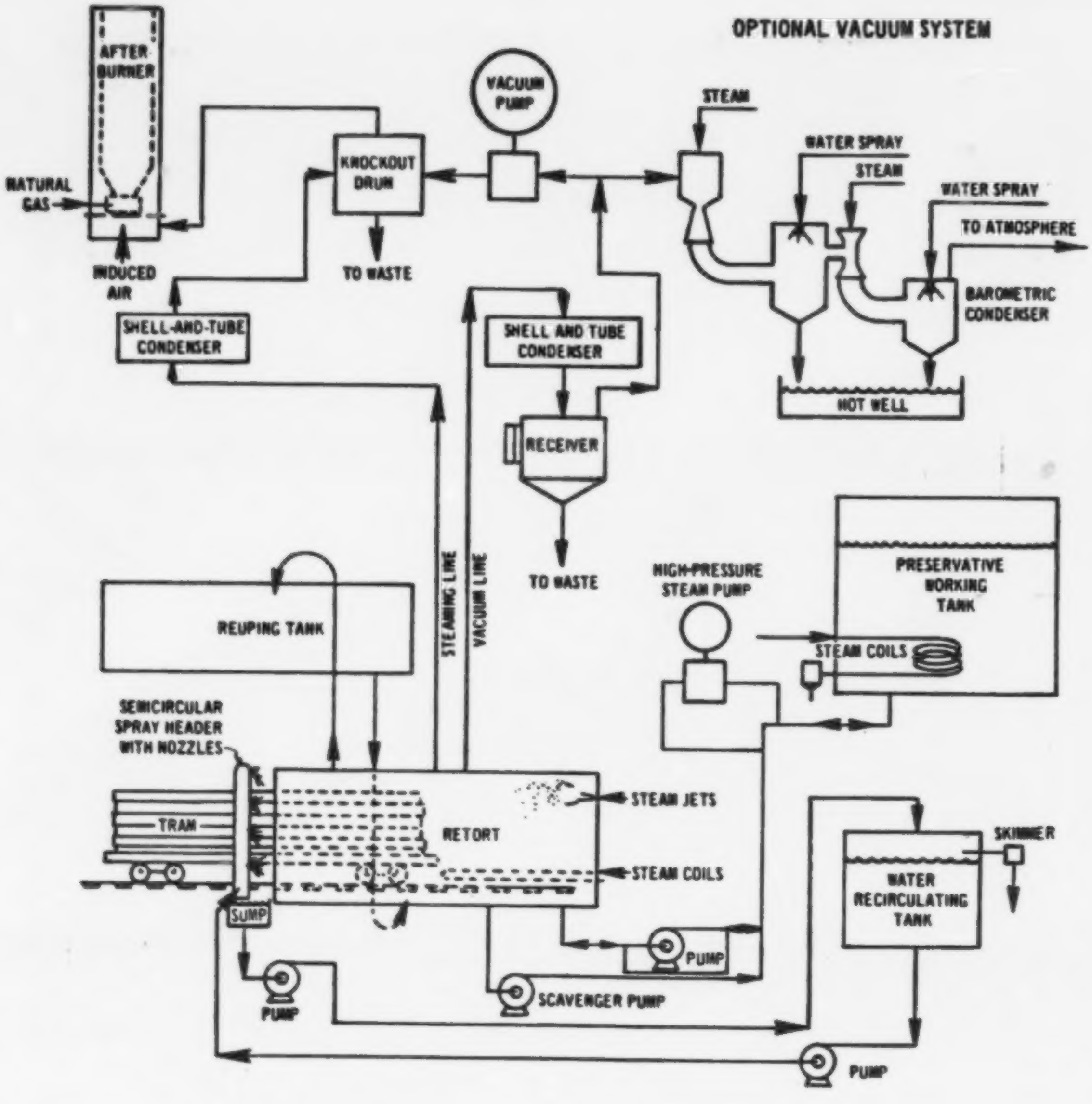

OPTIONAL VACUUM SYSTEM
AFTER BURNER
NATURAL GAS
INDUCED AIR
KNOCKOUT DRUM
TO WASTE
VACUUM PUMP
STEAM
WATER SPRAY
STEAM
WATER SPRAY
TO ATMOSPHERE
BAROMETRIC CONDENSER
HOT WELL
SHELL-AND-TUBE CONDENSER
SHELL AND TUBE CONDENSER
RECEIVER
TO WASTE
STEAMING LINE
VACUUM LINE
REUPING TANK
HIGH-PRESSURE STEAM PUMP
PRESERVATIVE WORKING TANK
STEAM COILS
SEMICIRCULAR SPRAY HEADER WITH NOZZLES
TRAM
RETORT
STEAM JETS
STEAM COILS
SUMP
SKIMMER
WATER RECIRCULATING TANK
PUMP
PUMP
SCAVENGER PUMP
PUMP

Figure 9. Diagram of a pressurized wood treating plant using creosote solutions or oilborne preservatives (Reference 27).

Empty cell processes achieve deep penetration of preservative; however, the cells are left only coated with preservative. Two empty cell processes are commonly employed: the Lowry process and the Rueping process.

In the Lowry process, the wood is placed in the retort, which is then filled with preservative. Pressure is applied to force the preservative into the wood, displacing the original air within the wood. After the required penetration is achieved, pressure is released and a vacuum is drawn. The compressed air within the wood, along with the vacuum, forces the excess preservative out of the wood voids, leaving them coated with preservative. The Rueping process is the same as the Lowry process except that the retort is air-pressurized before the preservative is added. This pressure is maintained while the preservative is added. Frequently, an equalizing tank (the Reuping tank) is used to store the preservative for this process, and the air in the treating cylinder is interchanged with the preservative in the storage tank. The extent of preservative recovery from this process is generally greater than with the Lowry process.

Another pressure treatment technique, the liquified petroleum (LP) gas process, employs a low-boiling-point solvent, such as butane, to carry the preservative into the wood. In some instances, an intermediate solvent is needed to dissolve the preservative. In this process, the cylinder is filled with a solventborne preservative and then pressurized. Once the desired preservative penetration is achieved, the pressure is released and the residual preservative drained off. A vacuum is applied to vaporize the carrier solvent, leaving the solid preservative impregnated in the wood.

The primary source of pollutants for these processes is a wastewater containing organic materials generated during the conditioning and treating cycles. The heat content of the steam volatilizes low-molecular-weight organic compounds such as benzene and toluene or atomizes drops of emulsified preservative, carrier oil, and water. These vapors are removed from the retort and condensed. The resulting condensate contains free oils (and preservatives), emulsified oils (and preservatives), and wood extractives. Following removal of the free oils, the condensate water is transported to a disposal facility.

Process emissions include fugitive emissions that occur when the pressure vessel (retort) is opened (releasing steam and organics), cooling and drying of the products, and open tank volatilization. Also, contaminants can be emitted from any forced evaporation device used to dispose of the accumulated wastewater. A more detailed discussion of emissions, discharges, and their waste disposal technology options is presented in Section 6.

To project the pollutant burden from these operations, one of the objectives of this report, it is necessary to establish the generation rates of the pollutant-bearing multimedia emissions. Such rates are established in the following subsection.

5.3 WASTEWATER GENERATION

The characteristics of wastewater produced by a particular plant is a function of the combined influence of several factors. These factors include:

- Treated wood production rate
- Moisture content and species of the wood
- Type of preservative used
- Conditioning/treating methods
- Effluent segregation
- Rainfall

Water contamination during penta and creosote treatments occur during the steaming or preconditioning cycles when the preservative (and carrier fluid) is in intimate contact with the steam (vapor). Upon condensing, the water will contain oily preserving contaminants typically separated for reuse. Following free oil removal, the wastewater for disposal remains. In addition to entrained oils, the wastewater can also contain wood extractives such as sugars. The chemicals present in the wastewater include phenols, chlorinated phenols, and PAH's such as naphthalene.

The wastewater can have a turbid appearance due to the presence of emulsified oils. Open steaming processes result in the greatest emulsification of oils, while modified closed steaming, closed steaming, and boultonizing processes produce lesser quantities.

Variations in the volume of wastewater produced are shown in Tables VIII through X. The volume of wastewater generated during open steaming as shown in Table VIII averaged 236 liters of wastewater for each cubic meter of wood produced. Likewise, closed steaming and boultonizing resulted in 60 l/m^3 and 139 l/m^3, respectively. Again, these quantities are a function of the conditioning method, moisture content in the wood, rainfall, and other diluting streams.

Concentration data for the components of the wastewater produced at plants using the steaming process (open or closed) are presented in Tables XI through XIV. Similar data for wastewater streams produced by boultonizing plants are presented in Tables XV through XVIII. It can be clearly seen that there is very little uniformity in the concentrations. This is due to the differences in the processing steps and to the degree of dilution occurring.

Dilution water is generated by such streams as cooling water, storm runoff, spills, leaks, and poor plant maintenance. Cooling water is used to cool condensers, air compressors, and vacuum pumps. Water used for surface condensers, air compressors, and dry-type vacuum pumps do not come in contact with the preservative. Water used in barometric condensers or wet-type vacuum pumps becomes contaminated with the preservatives. Though no longer a widespread industry practice, use of cooling water in open-loop or once-through plants can account for 80 percent of the total water discharge (Reference 23).

TABLE VIII. THE VOLUME OF WASTEWATER GENERATED AT 14 OPEN STEAMING PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant code number	Treated wood production	Wastewater volume generated	Volume per unit production
	m3/day	l/day	l/m3
1	22.6	6,740	298
2[a]	118	27,300[b]	231
3[a]	291	12,500	428
4[a]	231	62,500	270
5	120	11,400	94.9
6	186	18,900	102
7	31.4	37,800	1200
8	142	10,400	73.5
9	178	56,800	320
10[a]	238	53,000	187
11	40.9	9,460	231
12	109	21,800	277
13	29.4	11,400	385
14	174	37,800	435
Average	137	32,300	236

[a] Achieving no discharge
[b] Includes stormwater from treating area

TABLE IX. THE VOLUME OF WASTEWATER GENERATED AT EIGHT CLOSED STEAMING PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant code number	Treated wood production m^3/day	Volume generated l/day	Volume per unit production l/m^3
15[a]	139	11,400	81.6
16[a]	93.4	3,030	32.4
17[a]	173	12,500	72.3
18	74.1	9,460	128
19[a]	50.5	1,140	22.6
20	23.5	1,890	80.4
21[a]	10.2	1,320	130
22[b]	130	870	6.7
Average	86.7	5,200	60.0

[a] Achieving no discharge
[b] Data from 1975 Pretreatment Study

TABLE X. THE VOLUME OF WASTEWATER GENERATED AT 14 BOULTON CONDITIONING PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant code number	Treated wood production	Volume generated	Volume per unit production
	m^3/day	l/day	l/m^3
23[a]	508	26,500	52.1
24	57.7	3,790	65.5
25	209	26,500	127
26	240	18,900	78.9
27[a]	49.9	7,600	152
28[b]	47.1	19,100	405
29[b]	61.6	5,680	92.3
30[b]	125	9,500	76.2
31	239	56,800	238
32[a]	38.6	3,410	88.2
33[a]	202	20,800	103
34[a]	172	16,400	94.9
35[a]	150	65,500	436
36[c]	48.1	16,400	340
Average	153	21,210	139

[a] Achieving no discharge
[b] Data from 1975 Pretreatment Study
[c] Includes boiler blowdown, uncontaminated steam condensate

TABLE XI. ANALYSIS OF OIL AND GREASE AND CHEMICAL OXYGEN DEMAND IN WASTEWATERS FROM STEAM CONDITIONING PROCESS PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant number	Wastewater flow (1/day)	Wood production volume (m^3/day)	Oil and grease		Chemical oxygen demand	
			Concentration (mg/1)	Mass flow (g/m^3)	Concentration (mg/1)	Mass flow (g/m^3)
1	11,360	110	1,755	181.2	10,460	1,080
2	7,570	142	979.2	52.2	3,593	190
3	22,710	187	718.5	87.3	6,377	775
4	28,770	164	1,902	333.6	8,979	1,580
5[a]	34,520	280	143	17.6	14,600	1,800
6[b]	34,520	280	68.0	8.4	14,300	1,760
7	6,440	96	32.2	2.2	2,457	165
8	94,630	226	518.0	216.9	7,079	2,960
9	31,040	248	927.0	116.0	3,706	460
10	122,500	439	351.3	98.0	2,806	780
11	52,040	212	1,785	438.2	15,273	3,750
12	35,390	320	474.0	52.4	3,010	330
13	13,250	224	17	1.0	3,200	190
14	34,070	348	1,365	133.6	8,880	870
15	20,820	85	536.3	131.4	3,079	755
16	18,930	76	182.5	15,694	3,910	
17	160,500	515	460	143.3	1,900	590
18	7,570	85	773.0	68.8	7,116	630
19	236,600	461	950.2	487.6	8,844	4,540
20	94,630	198	5.3	1,356	650	
Average	55,490	230	793.8	151.8	7,928	1,345

[a] Data from creosote separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable). Not included in averages.

[b] Data from penta separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable). Not included in averages.

TABLE XII. ANALYSIS OF THE VOLATILE ORGANIC COMPONENTS IN WASTEWATERS FROM STEAM CONDITIONING PROCESS PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant number	Wastewater flow (l/day)	Wood production volume (m^3/day)	Methylene chloride		Trichloromethane		Benzene		Ethylbenzene		Toluene	
			Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)
5[a]	34,520	280	0.006	0.0007	--	--	0.003	0.0004	0.037	0.005	0.027	0.003
6[b]	34,520	280	--	--	--	--	0.013	0.002	0.170	0.02	0.170	0.02
10	122,500	439	0.702	0.20	--	--	1.05	0.29	0.867	0.24	2.84	0.79
13	13,250	224	0.280	0.02	0.02	0.001	2.80	0.17	2.10	0.12	3.20	0.19
17	160,500	515	0.077	0.02	--	--	1.62	0.50	0.38	0.12	0.50	0.16
Average	98,750	393	0.353	0.08	0.02	0.001	1.82	0.32	1.12	0.16	2.18	0.38

[a] Data from creosote separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable). Not included in averages.

[b] Data from penta separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable). Not included in averages.

-- Indicates that parameters were analyzed, but were below detection limit.

TABLE XIII. ANALYSIS OF THE PAH COMPONENTS IN WASTEWATERS FROM STEAM CONDITIONING PROCESS PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant number	Flow (1/day)	Production volume (m^3/day)	1		2		3		4		5		6		7		8	
			Conc (mg/1)	Flow (g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)
4	28,766	164	1.27	0.22	--	--	--	--	0.82	0.14	--	--	--	--	--	--	6.72	1.18
5[a]	34,519	280	35.0	4.31	0.09	0.01	--	--	22.0	2.71	0.04	0.01	0.13	0.02	--	--	14.0	1.73
6[b]	34,519	280	4.80	0.59	--	--	--	--	3.40	0.42	--	--	--	--	--	--	18.0	2.22
9	31,037	248	0.63	0.08	0.03	0.003	0.027	0.003	0.36	0.05	0.007	0.0008	--	--	--	--	2.52	0.32
10	122,483	439	6.43	1.79	1.68	0.47	1.68	0.47	4.85	1.35	1.35	0.38	0.490	0.14	0.315	0.09	11.5	3.21
12	35,390	320	0.87	0.10	--	--	0.017	0.002	0.64	0.07	--	--	--	--	--	--	1.95	0.22
13	13,248	224	17.0	1.01	--	--	3.90	0.23	13.0	0.77	2.70	0.16	5.50	0.33	0.006	0.0004	39.0	2.31
17	160,484	515	1.60	0.50	0.35	0.11	0.350	0.11	1.10	0.34	0.420	0.13	0.006	0.002	0.006	0.002	6.50	2.03
19	236,563	461	0.64	0.33	--	--	--	--	0.50	0.26	--	--	--	--	--	--	2.96	1.52
Average	89,710	339	4.1	0.58	0.69	0.19	1.19	0.16	3.0	0.43	1.12	0.17	2.00	0.16	0.109	0.03	10.2	1.54

(continued)

[a] Data from creosote separator (wasteloads cannot be calculated since few measurements for the individual operators were unobtainable). Not included in averages.

[b] Data from penta separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable). Not included in averages

-- Indicates that parameter was analyzed but was below detection limit

Key to Base Neutral Data Tables

1. Fluoranthene
2. Benzo (B) Fluoranthene
3. Benzo (k) Fluoranthene
4. Pyrene
5. Benzo (A) Pyrene
6. Indero (1, 2, 3-CD) Pyrene
7. Benzo (ghi) Perylene
8. Phenanthrene and/or Anthracene
9. Benzo (a) Anthracene
10. Dibenzo (a, h) Anthracene
11. Naphthalene
12. Acenaphthene
13. Acenaphthylene
14. Fluorene
15. Chrysene
16. Bis-2-ethyl-hexyl phthalate

TABLE XIII (concluded)

Plant number	Flow (l/day)	Production volume (m^3/day)	9		10		11		12		13		14		15		16	
			Conc (mg/l)	Flow (g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)
4	28,766	164	0.11	0.02	--	--	0.38	0.07	1.30	0.23	1.01	0.18	2.31	0.41	0.07	0.01	0.126	0.02
5[a]	34,519	280	7.70	0.95	--	--	45.0	5.55	55.0	6.78	1.20	0.15	48.00	5.92	4.70	0.58	--	--
6[b]	34,519	280	2.40	0.30	--	--	17.0	2.10	10.0	1.23	--	--	8.40	1.04	--	--	--	--
9	31,037	248	0.07	0.01	--	--	2.20	0.28	1.06	0.13	1.21	0.15	0.82	0.10	0.07	0.01	0.437	0.05
10	122,483	439	1.33	0.37	--	--	31.0	8.65	4.36	1.22	0.53	0.15	3.59	1.00	1.43	0.40	--	--
12	35,390	320	0.16	0.02	--	--	0.97	0.11	1.46	0.16	0.93	0.10	1.01	0.11	0.25	0.03	0.087	0.01
13	13,248	224	7.40	0.44	0.430	0.03	34.7	2.05	15.0	0.89	1.10	0.07	11.0	0.65	--	--	--	--
17	160,484	515	--	--	--	--	3.47	1.08	1.70	0.53	0.006	0.002	1.50	0.47	0.93	0.29	--	--
19	236,563	461	0.09	0.05	--	--	0.46	0.24	1.11	0.57	0.73	0.37	1.11	0.57	0.10	0.05	0.201	0.10
Average	89,710	339	1.53	0.15	0.43	0.03	10.5	1.78	3.71	0.53	0.79	0.15	3.05	0.47	0.48	0.13	0.213	0.05

[a] Data from creosote separator (wasteloads cannot be calculated since few measurements for the individual operators were unobtainable. Not included in averages.

[b] Data from penta separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable. Not included in averages

-- Indicates that parameter was analyzed but was below detection limit

Key to Base Neutral Data Tables

1. Fluoranthene
2. Benzo (B) Fluoranthene
3. Benzo (k) Fluoranthene
4. Pyrene
5. Benzo (A) Pyrene
6. Indero (1, 2, 3-CD) Pyrene
7. Benzo (ghi) Perylene
8. Phenanthrene and/or Anthracene
9. Benzo (a) Anthracene
10. Dibenzo (a, h) Anthracene
11. Naphthalene
12. Acenaphthene
13. Acenaphthylene
14. Fluorene
15. Chrysene
16. Bis-2-ethyl-hexyl phthalate

TABLE XIV. ANALYSIS OF THE PHENOLIC COMPONENTS IN WASTEWATERS FOR STEAM CONDITIONING PROCESS PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant number	Wastewater flow (l/day)	Production volume (m^3/day)	Phenol		2-Chlorophenol		2,4-Dimethylphenol		2,4,6-Trichlorophenol		Penta	
			Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)
1	11,360	110	NA	--	NA	--	NA	--	NA	--	306.0	31.6
2	7,570	142	NA	--	NA	--	NA	--	NA	--	49.0	2.61
3	22,710	187	NA	--	NA	--	NA	--	NA	--	34.5	4.2
4	28,766	164	NA	--	NA	--	NA	--	NA	--	6.3	1.11
5[a]	34,519	280	9.2	1.13	--	--	--	--	--	--	16.0	1.97
6[b]	34,519	280	1.4	0.17	--	--	--	--	--	--	25.0	3.08
8	94,625	226	NA	--	NA	--	NA	--	NA	--	24.5	10.2
9	31,037	248	NA	--	NA	--	NA	--	NA	--	158.0	19.8
10	122,483	439	24.4	6.81	0.042	0.01	0.13	0.04	0.252	0.07	9.4	2.63
11	52,044	212	NA	--	NA	--	NA	--	NA	--	26.7	6.6
12	35,390	320	NA	--	NA	--	NA	--	NA	--	22.3	2.47
13	13,248	224	87.0	5.15	--	--	6.60	0.39	--	--	1.2	0.07
14	34,065	348	NA	--	NA	--	NA	--	NA	--	47.8	4.7
15	20,818	85	NA	--	NA	--	NA	--	NA	--	17.9	4.4
17	160,484	515	16.0	4.99	0.015	0.005	5.50	1.71	0.533	0.17	2.7	0.84
18	7,570	85	NA	--	NA	--	NA	--	NA	--	50.3	4.51
19	236,563	461	NA	--	NA	--	NA	--	NA	--	57.1	29.3
Average	51,690	222	42.5	5.65	0.029	0.01	4.08	0.71	0.393	0.12	47.9	7.36

NA -- Not analyzed

-- Indicates that parameter below detection limit if analysis was conducted.

[a] Data from creosote separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable). Not included in averages.

[b] Data from penta separator (wasteloads cannot be calculated since flow measurements for the individual separators were unobtainable). Not included in averages.

TABLE XV. ANALYSIS OF OIL AND GREASE IN COD WASTEWATERS FROM BOULTON CONDITIONING PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant number	Wastewater flow (l/day)	Production volume (m^3/day)	Oil and grease		Chemical oxygen demand	
			Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)
21	18,925	142	34.7	4.62	1,711	1,228.0
22	8,327	78	164	17.5	520	55.5
23	28,388	62	1357	621.3	7,316	3,349.8
24	26,495	283	12.3	1.15	3,704	346.8
25	57,911	308	39.4	7.41	5,797	1,089.9
Average	28,009	175	321.5	130.4	3,810	1,214.0

TABLE XVI. ANALYSIS OF THE VOLATILE ORGANIC COMPONENTS IN WASTEWATERS FROM BOULTON CONDITIONING PROCESS PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant number	Wastewater flow (l/day)	Production volume (m^3/day)	Methylene chloride		Trichloromethane		Benzene		Ethylbenzene		Toluene	
			Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)
26[a]	8,327	78	2.60	0.28	0.009	0.0009	--		--		--	

[a] Plant uses methylene chloride as a carrier solvent in a proprietary treatment process. Not included in averages.

-- Indicates that parameter was analyzed for but was below detection limit.

TABLE XVII. ANALYSIS OF THE PAH COMPONENTS IN WASTEWATERS FROM BOULTON CONDITIONING PROCESS PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

Plant number	Flow (l/day)	Production volume (m^3/day)	1		2		3		4		5		6		7		8	
			Conc (mg/l)	Flow, (g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)	(mg/l)	(g/m^3)
27[a]	8,327	78	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.929	0.10
28[a]	24,792	62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	57,911	308	0.282	0.05	--	--	--	--	0.194	0.04	--	--	--	--	--	--	1.51	0.28
Average	30,343	149	0.282	0.05	--	--	--	--	0.194	0.04	--	--	--	--	--	--	1.22	0.19

(continued)

[a] These plants were treating solely with penta and not creosote formulation during the sampling period.
-- Indicates that parameter was analyzed but was below detection limit

Key to Base Neutral Data Tables

1. Fluoranthene
2. Benzo (B) Fluoranthene
3. Benzo (k) Fluoranthene
4. Pyrene
5. Benzo (A) Pyrene
6. Indero (1, 2, 3-CD) Pyrene
7. Benzo (ghi) Perylene
8. Phenanthrene and/or Anthracene
9. Benzo (a) Anthracene
10. Dibenzo (a, h) Anthracene
11. Naphthalene
12. Acenaphthene
13. Acenaphthylene
14. Fluorene
15. Chrysene
16. Bis-2-ethyl-hexyl phthalate

TABLE XVII (concluded)

			9		10		11		12		13		14		15		16	
Plant number	Flow (1/day)	Production volume (m^3/day)	Conc (mg/1)	Flow (g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)	(mg/1)	(g/m^3)
27[a]	8,327	78	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28[a]	24,792	62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.433	0.17
29[b]	57,911	308	0.034	0.01	--	--	3.14	0.59	2.83	0.53	2.06	0.39	0.824	0.15	0.018	0.003	1.46	0.27
Average	25,788	213	0.034	0.01	--	--	3.14	0.59	2.83	0.53	2.06	0.39	0.824	0.15	0.018	0.003	0.95	0.23

TABLE XVIII. ANALYSIS OF THE PHENOLIC COMPONENTS IN WASTEWATERS FROM BOULTON CONDITIONING PROCESS PLANTS AS A FUNCTION OF TREATED WOOD PRODUCTION (Reference 27)

			Phenol		2-Chlorophenol		2,4-Dimethylphenol		2,4,6-Trichlorophenol		Penta	
Plant number	Wastewater flow (l/day)	Production volume (m^3/day)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)	Concentration (mg/l)	Mass flow (g/m^3)
21	18,925	142	NA	--	NA	--	NA	--	NA	--	5.70	0.76
22	8,327	78	0.071	0.01	--	--	--	--	--	--	27.0	2.88
24	26,495	283	NA	--	NA	--	NA	--	NA	--	0.09	0.01
Average	17,916	168	0.071	0.01	--	--	--	--	--	--	10.9	1.22

NA -- Not Analyzed

-- Indicates that parameter was below detection limit if analysis conducted.

Boiler blowdown water will not be contaminated with organic preservatives but may contain chromate, phosphates, or other chemicals used as boiler water conditioning additives. The effluent wastes from the water treatment plant, if any, may also contain salts of sodium chloride and calcium carbonate (hardness).

Finally, water used for plant cleanup, plant site runoff water due to rainfall, or water from other nonprocess-related sources may also come in contact with the preservatives. Although the concentration of contaminants in these streams is less than that in the condensate water from the preservative cycle, the flows do increase the volume of wastewater requiring disposal.

5.4 AIR EMISSIONS

Low-molecular-weight organic compounds vaporize in the retort during the high-temperature preservative application cycles. During charge changes, these organics are released as fugitive emissions through the open door of the retort and form a dense white plume (Reference 28). In addition, the wood removed from the retort also emits material as a white plume, that may exceed 40 percent opacity after 20 minutes (Reference 28). Qualitative and quantitative organic analyses for specific pollutants in these emissions have not been identified. However, it is expected that benzene, toluene, phenol, and similar volatile and low-molecular weight compounds would be present.

Other emissions include the vacuum exhaust and other vents from the retorts. Source tests at one mill measured 2.2 g/m^3 (0.95 grain/scf) of aerosol in 12.5 m^3/min (440 scfm) of gas from a vacuum pump vent. Steam cleaning released 44 g/m^3 of aerosol in a 13 m^3/min stream (Reference 28). Again, qualitative and quantitative analyses of the organic constituents were not identified.

The expanded use of forced evaporation devices on the generated wastewater can lead to increased air emissions. These emissions, characterized in Section 6, include the low-volatile- and low-molecular-weight compounds similar to those emitted from the retort. The forced evaporation devices include thermal evaporation, cooling towers, and spray ponds. In brief, thermal evaporation can volatilize the organic constituents, and cooling towers, and spray ponds can result in organic ladened drift (aerosols) that escape from the boundaries of the evaporation devices.

Finally, fugitive emissions from preservative handling, transport, leaks, and vents, can also occur. No qualitative or quantitative data is available to characterize emissions from these sources.

5.5 SOLID WASTES

Solid wastes are generated from wood preparation activities and the treatment of accumulated wastewater. This latter source may include the solids remaining after flocculation of the wastewater to break the emulsions that remain following free oil removal and/or the residue that remains following evaporation of the excess water fraction. Typically, these wastes are removed from the plant for disposal in a landfill. Another disposal option is incineration; however, case histories for this procedure have not been developed.

EPA has tested samples of solid waste residues that remain following wastewater treatment activities. It was found that the wastes contain PAH's and phenolic compounds. The sampling and analysis of the waste was performed as part of the plant studies for the wood preservatives industry in the "Indicatory Fate Study" by the Robert S. Kerr Environmental Research Laboratory in Ada, Oklahoma (Reference 29).

Two plants, labeled Plant 10 and Plant 11, were sampled. At Plant 10, two sediment samples were taken: one from the aerated lagoon, and one from the final retention pond. The analytical data for Plant 10 are summarized in Table XIX. At Plant 11, one sediment sample was taken from the aerated lagoon. The analytical data for Plant 11 are summarized in Table XX.

Other qualitative information concerning wood treating wastes have been reported. A contractor/hauler that disposes of this waste for a wood treatment plant has provided an analysis of the waste for EPA. This analysis is summarized in Table XXI.

Treating plant waste materials are characterized by an almost infinite variety of compositions. This is due to the various types of treating processes, preservatives, and wastewater processing that generates the solid waste material. Further, though estimates of the volume of solid waste generated have been presented, there is uncertainty in these estimates due to the nonuniformity of treating mechanisms within the industry.

5.6 PLANT POPULATION AND POLLUTANT BURDEN

The American Wood Preservers' Association (AWPA) Wood Preservation Statistics for 1978 reports 476 existing wood preserving plants in the United States. Of the 326 plants responding to an AWPA survey (Reference 30), over 84.4 percent are pressure treating plants, 3.4 percent are nonpressure plants, with the balance having both pressure and nonpressure facilities. Fifty-eight percent of the pressure treating plants are located in the southeast and south central regions as shown in Table XXII. The remaining plants are concentrated in the North Central, Pacific, Northeast, and Rocky Mountain regions. A listing of those pressure treating plants that use creosote and/or penta as preservatives are presented in Table XXIII. Table XXIV presents the total volume of wood treated with organic preservatives.

To project the potential pollutant burden generated by the wood preserving industry, certain assumptions have been made. First, the average wastewater generation rates in Tables VIII through X are representative of the pressure treating sector as a whole. Secondly, the average concentration values for the selected compounds from Tables XI through XIX are representative of the industry. These guidelines allow for the calculation of total wastewater generation rate projections. The open and closed steaming processes wastewater generation rates are 236 l/m^3 and 60 l/m^3 of product (from Tables VIII and IX, respectively). The generation rate for Boulton conditioning is 139 l/m^3 of product (from Table X).

TABLE XIX. ANALYTICAL DATA -- PLANT 10 (Reference 29)

	Bottom sediment dry weight	
	Aerated lagoon (μg/kg)	Final pond (μg/kg)
PAH's		
Benzo(a)anthracene	3,700	149
Chrysene	4,500	2,060
Fluorene	17,600	210
Penanthrene/anthracene	19,500	3,390
Pyrene	5,300	4,140
Phenolics:		
Phenol	9,030	16,000
2,4-dimethylphenol	4,398	3,418
2-chlorophenol	396,000	1,200
2,4,6-trichlorophenol	No data	25,000
Penta	302,000	58,000

From the volume of wood treated in 1978 (Table XXIV), the average wastewater compositions for steaming and Boulton conditioning plants (Tables XI through XVIII), and from the preceding wastewater generation rates, estimates of the rate of discharge of specific compounds can be made. The calculated values for selected organic compounds are presented in Table XXV. These values will be used as the basis for projection of the pollutant burden as generated by the wood preserving industry. The values represent the mass of pollutant contained in the wastewater to be treated and disposed of.

TABLE XX. ANALYTICAL DATA -- PLANT 11 (Reference 29)

	Bottom sediment dry weight
	Aerated lagoon (μg/kg)
PAH's	
Benzo(a)anthracene	1,250
Benzo(a)pyrene	5,980
Chrysene	9,280
Acenaphthylene	1,400
Fluorene	547
Phenanthrene/anthracene	43,700
Pyrene	4,250
Acenaphthene	1,840
Phenolics	
Phenol	4,500
2-chlorophenol	300
Penta	4,800

TABLE XXI. ANALYSIS OF WOOD TREATING PLANT SOLID WASTE (Reference 31)

Component	Concentration (mg/l)
Total phenols	5,043
Penta	34
Dinitrophenol	24
Creosote	10,000

TABLE XXII. WOOD PRESERVING PLANTS IN THE UNITED STATES BY STATE AND TYPE RESPONDING TO THE 1978 SURVEY BY THE AWPA (Reference 30)

	Pressure	Nonpressure	Pressure & nonpressure	No. of plants	Not reporting
Northeast					
Delaware	0	0	0	0	0
Maine	0	0	0	0	0
Maryland	4	0	1	5	4
Massachusetts	2	0	0	2	0
New Hampshire	0	0	1	1	0
New Jersey	3	0	0	3	1
New York	5	0	0	5	3
Pennsylvania	7	0	2	9	5
Rhode Island	0	0	0	0	1
West Virginia	3	0	0	3	4
Total	24	0	4	28	19
North Central					
Ilinois	7	1	0	8	2
Indiana	5	0	0	5	1
Iowa	0	0	0	0	1
Kentucky	5	0	0	5	2
Michigan	4	0	0	4	7
Minnesota	5	0	2	7	2
Missouri	8	0	1	9	0
Nebraska	1	0	0	1	1
North Dakota	0	0	0	0	0
Ohio	7	0	0	7	4
Wisconsin	9	1	2	12	2
Total	51	2	5	58	22
Southeast					
Florida	16	1	4	21	12
Georgia	26	0	1	27	9
North Carolina	10	0	4	14	5
South Carolina	8	0	2	10	7
Virginia	15	0	1	16	4
Puerto Rico	1	0	0	1	0
Total	76	1	12	89	37

(continued)

TABLE XXII (concluded)

	Pressure	Nonpressure	Pressure & nonpressure	No. of plants	Not reporting
South Central					
Alabama	18	0	3	21	12
Arkansas	10	0	1	11	10
Louisiana	15	1	1	17	10
Mississippi	16	0	1	17	10
Oklahoma	3	0	1	4	4
Tennessee	2	1	0	3	3
Texas	20	0	2	22	10
Total	84	2	9	95	59
Rocky Mountain					
Arizona	0	1	0	1	1
Colorado	3	0	0	3	0
Idaho	4	1	2	7	3
Montana	3	1	2	6	1
New Mexico	1	0	0	1	0
South Dakota	1	0	0	1	0
Utah	1	1	0	2	0
Wyoming	3	0	0	24	5
Total	16	4	4	24	5
Pacific					
California	6	0	2	8	2
Oregon	7	0	2	9	0
Washington	9	2	2	13	4
Hawaii	2	0	0	2	2
Total	24	2	6	32	8
United States Total	275	11	40	326	150

TABLE XXIII. WOOD PRESERVING PLANTS IN THE UNITED STATES AS REPORTED BY THE AWPA (Reference 30)

				Pressure cylinders		
Managing company	Headquarters	Plant location	Preservatives used[a]	No.	Diameter (inches)	Length (feet)
Acme Wood Preserving, Inc.	Princeton, WV	Princeton, WV	C	1	72	54
American Creosote Works, Inc.	Pensacola, FL	Pensacola, FL	CO	1	72	127
				1	72	147
		Jackson, TN		1	105	172
		Louisville, MS		2	96	150
American Crossarm & Conduit Co.	Chehalis, WA	Chehalis, WA	O	2	60	77
American Wood Preserving Co.	Americus, GA	Americus, GA	C	1	63	64
Angelina Hardwood Sales Co.	Lufkin, TX	Lufkin, TX	O	1	60	26
Appalachian Timber Services, Inc.	Charleston, WV	Sutton, WV	CW	2	72	75
				1	84	40
		White Plains, KY	CW	1	72	60
				2	48	40
Atchison, Topeka, & Santa Fe Railway Co.	Chicago, IL	Somerville, TX	COW	4	96	155
				-	72	132
Atlantic Creosote Co., Inc.	Portsmouth, VA	Portsmouth, VA	CO	1	96	133
				2	96	153
	Hainesport, NJ	Hainesport, NJ	C	1	84	106
				1	84	126
	Savannah, GA	Savannah, GA	CO	3	96	140
Atlantic Wood Industries, Inc.	Savannah, GA	Savannah, GA	COW	3	96	140
		Portsmouth, VA		2	96	153
				1	96	133
		Hainesport, NJ		2	84	126
		Vidalia, GA		1	84	124
		Athens, NY		1	72	80
		Fruitland, MD		1	72	80
Baldwin Pole and Piling Co.	Bay Minette, AL	Bay Minette, AL	CO	2	72	120
Baxter, J. H. & Co.	San Mateo, CA	The Dalles, OR	COWF	5	84	132
		Eugene, OR	COWF	1	72	50
				1	72	157
				1	96	80
				1	96	135
				1	96	146
		Long Beach, CA	OWF	1	96	134
				1	96	132
				1	96	136
		Renton, WA	O	1	96	144
		Weed, CA	CDWF	2	100	65
				1	100	120
		Laramie, WY	CO	4	84	132
Olon Belcher Lumber Co.	Brent, AL	Brent, AL	OW	1	96	50
				1	96	87
Benton Creosoting Division, Kennedy Saw	Shreveport, LA	Benton, LA	C	1	72	92
Birmingham Wood Preserving Corp.	Birmingham, AL	Birmingham, AL	C	1	72	52
				1	72	73
Bouma Post Yards	Choteau, MT	Choteau, MT	OW	1	48	42
				1	54	36
Broderick Wood Products Co.	Denver, CO	Denver, CO	CO	2	96	110
Burke-Parsons-Bowlby Corp.	Spencer, WV	Billings, WV	CW	2	84	48
		Goshen, VA	CW	1	84	45
				1	84	54
				1	84	70
		Stanton, KY	CW	1	60	45
				1	60	40
		DuBois, PA	C	2	84	48
Burlington Northern, Inc.	St Paul, MN	Brainerd, MN	C	2	84	133
		Paradise, MT	C	2	84	133
Cahaba Lumber Co.	Centreville, AL	Centreville, AL	O	1	96	80
				1	96	50
Cahaba Pressure Treated	Brierfield, AL	Brierfield, AL	C	2	72	36
				1	72	81

(continued)

TABLE XXIII (continued)

				Pressure cylinders		
Managing company	Headquarters	Plant location	Preser-vatives used[a]	No.	Diameter (inches)	Length (feet)
Carbolineum Wood Preserving Co.	Milwaukee, WI	Milwaukee, WI	C			
Carney, B. J. & Co.	Spokane, WA	Madera, CA	OW	1	72	100
Carolina Creosote Corp., Inc.	Leland, NC	Leland, NC	C	1	72	37
				1	72	58
Carolina Wood Preserving Co., Inc.	Scotland Neck, NC	Scotland Neck, NC	COW	1	84	50
				1	60	50
				2	72	50
Cascade Pole Division, McFarland Cascade	Tacoma, WA	Tacoma, WA	COW	1	96	40
				1	96	105
				2	96	95
Cass County Treating Co.	Lindon, TX	Lindon, TX	0	1	72	72
				1	72	60
Central Forest Products, Inc.	Shawnee Mission, KS	Hugo, OK	0	1	72	50
				1	72	72
Coleman-Evans Wood Preserving Co.	Jacksonville, FL	Whitehouse, FL	0	1	72	72
Colfax Creosote Company	Pineville, LA	Pineville, LA	CO	1	100	108
				1	100	110
				1	72	50
The Colwood Company, Inc.	Columbia, SC	Columbia, SC	OW	1	60	50
				1	72	80
Conroe Creosoting Company	Conroe, TX	Conroe, TX	COW	1	72	82
				1	72	72
				2	72	142
				1	72	75
Cowboy Timber Treating, Inc.	Manderson, WY	Manderson, WY	0	1	72	65
Cox Wood Preserving Company	Orangeburg, SC	Orangeburg, SC	OWF	1	60	50
				1	60	58
				1	72	80
				1	72	50
				1	72	82
Crown Zellerbach Treated Wood Products	Gulfport, MS	Urania, LA	CO	1	108	150
				1	108	125
		Gulfport, MS	CO	3	84	150
		Mobile, AL	CO	1	84	120
				1	84	150
Dant & Russell, Inc.	Portland, OR	North Planes, OR	COW	1	72	162
				1	72	152
				1	72	121
				1	72	60
Davis Timber Co., Inc.	Hattiesburg, MS	Hattiesburg, MS	0	1	72	151
Duke City Lumber Co.	Livingston, TX	Livingston, TX	CO	1	72	90
				2	72	50
Durable Wood Preservers, Inc.	Charlotte, NC	Charlotte, NC	OW	1	72	51
				1	72	52
				1	60	67
El Dorada Pole & Piling Co., Inc.	El Dorada, AR	El Dorada, AR	CO	1	72	92
				1	72	110
Elijay Lumber Co.	Elijay, GA	Elijay, GA	0	1	36	24
Eppinger & Russel			C			
Escambia Treating Company	Pensacola, FL	Pensacola, FL	0	1	72	142
				1	72	120
		Brunswick, GA	OW	1	84	140
				2	84	120
		Camilla, GA	CO	1	84	85
				1	84	120
Evr-Wood Treating Co., Inc.	Jennings, LA	Jennings, LA	CO	1	60	90
				1	60	36
Fernwood Industries	Fernwood, MS	Fernwood, MS	CO	1	100	100
				2	100	130
Florida Fence Post Co., Inc.	Ona, FL	Ona, FL	OC	2	60	74
Follen Wood Preserving Company	Jackson, MS	Elliott, MS	OW	2	72	60
				1	66	60
		Jackson, MS	OW	1	48	36
For-Tek			CO			
Frank Brooks Manufacturing Co.	Bellingham, WA	Bellingham, WA	CO			

(continued)

TABLE XXIII (continued)

Managing Company	Headquarters	Plant location	Preservatives used[a]	Pressure cylinders		
				No.	Diameter (inches)	Length (feet)
Garland Creosoting Co.	Longview, TX	Longview, TX	C	1	72	77
				1	72	50
Gateway Forest Products, Inc.	Mather, PA	Mather, PA	C	1	72	72
Glacier Park Co., Somers Lumber Division	Somers, MT	Somers, MT	C	2	96	122
Glennville Wood Preserving Co., Inc.	Glenville, GA	Glennville, GA	C	1	72	68
Haley, R. G., International Corp., Inc.	Bellingham, WA	Bellingham, WA	O	1	84	85
Fred M. Hallman Lumber Co.	Centreville, AL	Centreville, AL	O	1	72	36
Hart Creosoting Company	Jasper, TX	Jasper, TX	C	2	72	105
Hatheway & Patterson Co., Inc.	Mansfield, MA	Mansfield, MA	OW	1	48	42
				1	72	40
Hatheway-Patterson Corp.	Houston, TX	Houston, TX	O	1	48	60
Hawaii Wood Preserving, Inc.	Honolulu, HI	Honolulu, HI	OW	1	72	66
				1	72	60
		Kaluiui, Maui	OW	1	72	66
				1	48	42
Edwin Hines Lumber Co.			CO			
Holcomb Creosote Company	Yadkinville, NC	Yadkinville, NC	C	1	60	64
Hoosier Wood Preservers, Inc.	Indianapolis, IN	Indianapolis, IN	OW	1	84	40
				1	72	42
Hoover Universal	Pine Bluff, AR	Pine Bluff, AR	OWFG	1	48	45
				3	66	66
				1	72	50
Houston Chemical Service, Inc.	Houston, TX	Houston, TX	OF	2	72	40
				1	72	50
Huffman Wood Preserving, Inc.	Broken Bow, OK	Broken Bow, OK	O	2	72	72
Hughes Brothers, Inc.	Seward, NE	Seward, NE	O	1	72	42
				1	72	65
Idaho Pole Division, McFarland Cascade	Bozeman, MT	Bozeman, MT	O	1	96	147
International Paper Co., Wood Preserver Division	De Ridder, LA	De Ridder, LA	CO	3	100	108
	Joplin, MO	Joplin, MO	CO	1	96	65
				1	96	120
	Longview, WA	Longview, WA	CO	1	96	80
International Paper Co., Wood Preserver Div. (Cont.)	Longview, WA	Longview, WA	CO	1	96	142
	Navasota, TX	Navasota, TX	CO	3	72	110
International Paper Co.	Wiggins, MS	Wiggins, MS	CO	2	96	94
				1	96	144
Jasper Creosoting Company	Jasper, TX	Jasper, TX	CO	1	72	48
				2	72	110
Jennison-Wright Corp.	Toledo, OH	Granite City, IL	CO	3	74	140
		Toledo, OH	C	3	72	130
Joslyn Mfg. & Supply Company	Minneapolis, MN	Minneapolis, MN	OW	1	96	125
				1	120	100
	Woodstock, IL	Richton, MS	CO	1	72	122
	Portland, OR	Portland, OR	O	1	84	54
	Rattan, OK	Rattan, OK	C	1	102	123
Kerr-McGee Chemical Corp., Forest	Oklahoma City, OK	Avoca, PA	C	2	84	150
		Indianapolis, IN	C	3	84	148
		Kansas City, MO	C	2	84	132
		Madison, IL	C	2	84	132
				1	84	146
				1	84	150
		Meridian, MS	CO	3	84	150
		Milwaukee, WI	C	3	74	132
		Bossier City, LA	C	2	48	90
		Springfield, MO	C	2	84	132
		Texarkana, TX	CO	1	100	80
				2	110	165
		Columbus, MS	C	3	96	100

(continued)

TABLE XXIII (continued)

				Pressure cylinders		
Managing Company	Headquarters	Plant Location	Preservatives used[a]	No.	Dia. (inches)	Length (feet)
Koppers Co., Inc., Forest Products Division	Pittsburg, PA	Baltimore, MD	CWF	1	72	80
				1	72	140
		Carbondale, IL	C	4	74	131
		Charleston, SC	COW	4	96	133
		Denver, CO	COWFG	1	84	87
				1	72	133
				1	84	132
				1	96	170
		Florence, SC	CWF	1	96	55
				1	100	65
				2	96	125
				1	96	135
				1	100	180
	Pittsburg, PA	Gainseville, FL	COW	1	100	65
				1	72	132
				1	74	142
				1	74	132
		Galesburg, IL	C	1	72	132
				2	96	132
		Green Spring, WV	C	3	84	132
		Grenada, MS	CO	1	72	167
				4	72	130
		Guthrie, KY	C	2	84	132
		Houston, TX	COW	1	72	132
				1	96	155
				2	96	92
				1	96	132
		Kansas City, MO	C	1	96	114
				2	90	114
		Montgomery, AL	COG	1	96	51
				2	96	133
				2	96	132
				1	96	128
				1	96	125
		Montgomery, PA	C	3	96	140
		Neshua, NH	CO	3	90	51
				1	90	130
		N. Little Rock, AR	CO	6	72	130
		Oroville, CA	COWFG	2	100	65
				2	96	125
				1	100	132
				1	96	132
		Orrville, OH	CWF	1	96	87
				1	90	36
				3	90	87
		Fort Newark, NJ	CWF	1	100	65
				1	100	102
		Richmond, VA	C	1	100	110
				1	96	132
		Salem, VA	C	3	96	140
		Salisbury, MD	CWF	1	72	85
				3	72	167
				4	96	105
		Superior, WI	CO	1	90	124
Langdale Co., The	Valdosta, GA	Valdosta, GA	COW	3	96	80
				1	96	120
Lufkin Creosoting Co., Inc.	Lufkin, TX	Lufkin, TX	C	1	72	148
				1	84	80
MacGillis & Gibbs Co.	Milwaukee, WI	New Brighton, MN	OWF	1	72	50
Macon Creosote & Wood Preservers, Inc.	Macon, MS	Macon, MS	C	1	60	60
Madison Wood Preservers, Inc.	Madison, VA	Madison, VA	OW	1	60	32
				2	72	50

(continued)

TABLE XXIII (continued)

Managing Company	Headquarters	Plant Location	Preservatives used[a]	Pressure cylinders		
				No.	Dia. (inches)	Length (feet)
Marion Pressure Treating Co.	Marion, LA	Marion, LA	C	1	60	64
				1	72	112
Martin Piling & Lumber Co.			CO			
Masonite Corporation	Hattiesburg, MS	Hattiesburg, MS	OW	1	72	98
				2	72	85
McArthur Lumber & Post Co., Inc.	McArthur, OH	McArthur, OH	COW	2	72	41
				1	72	66
McCormick & Baxter Creosoting Co.	Portland, OR	Portland, OR	COWFG	1	96	90
				2	96	144
				1	96	145
		Stockton, CA	COWFG	1	72	65
				1	78	134
				1	84	142
				1	84	145
				1	84	176
McCranie Bros., Wood Preserving Co.	Willacoochee, GA	Willacoochee, GA	COW	1	72	82
				1	84	134
McFarland, L. D., Division, McFarland Cascade	Sandpoint, ID	Sandpoint, ID	CO	2	84	143
Mellott Wood Preserving Co.	Needmore, PA	Needmore, PA	C	1	84	54
Meredith, W. C., Co., Inc.	East Point, GA	East Point, GA	CO	1	72	54
				1	96	92
Miller, T. R., Mill Co., Inc.	Brewton, AL	Brewton, AL	COW	1	72	85
				1	96	105
				1	96	110
				1	96	120
Mississippi Wood Preserving Co.	Brookhaven, MS	Brookhaven, MS	CO	2	96	112
Missouri Wood Treating Co.	Raymondville, MO	Raymondville, MO	0	1	72	50
Mixon Bros. Wood Preserving, Inc.	Idabel, ID	Idabel, ID	CO	2	84	74
Montana Pole and Treating Plant	Butte, MT	Butte, MT	0	2	84	66
				1	72	85
Mountain Gravel and Construction	Dolores, CO	Dolores, CO	0	1	72	36
Mt. Pine Pressure Treating Co.	Plainview, AR	Plainview, AR	OW	1	60	60
National Wood Preservers, Inc.	Havertown, PA	Havertown, PA	OWF	1	60	40
				2	72	50
New South Forest Industries (formerly Coastal Carolina Wood Preserving Co.)	Conway, SC	Red Hill, SC	C	1	72	62
				1	48	40
Olivet Treated Products Co., Inc.	Hammond, LA	Hammond, LA	C	1	72	82
				1	72	152
				1	72	182
Ouacnita-Nevada Treating Co.	Chidester, AR	Reader, AR	CO	1	72	38
				1	62	55
Pearl River Wood Preserving Corp.	Picayune, MS	Picayune, MS	C	2	72	96
Penta Wood Products, Inc.	Siren, WI	Siren, WI	OW	1	72	93
				1	72	45
Permapost Products Co.			0			
Plainview Lumber Co., Inc.	Plainview, AR	Plainview, AR	OW	1	48	36
				1	72	60
Pressure Treated Timber Co.	Boise, ID	Boise, ID	0	1	72	50
R&K Creosote Co., Inc.	Natalbany, LA	Natalbany, LA	COW	1	84	70
				3	48	70
Rodman Industries, Inc.	Rock Island, IL	Rock Island, IL	0	1	81	12
Santa Fe Centralized Tie Plant	Somerville, TX	Somerville, TX	CW	4	96	155
				1	72	132
Saunders Supply Co.	Suffolk, VA	Suffolk, VA	OW	1	60	32
				1	60	50
				1	48	36
Scotch Lumber Co.	Fulton, AL	Fulton, AL	0	1	72	50
				1	72	110
Seaman Timber Company, Inc.	Montevallo, AL	Montevallo, AL	CWF	2	48	50
				1	48	70
				1	48	51
				1	72	50
Selma Pressure Treating Co., Inc.	Selma, CA	Selma, CA	OW	2	72	60

(continued)

TABLE XXIII (continued)

Managing Company	Headquarters	Plant Location	Preser-vatives used[a]	Pressure cylinders No.	Dia. (inches)	Length (feet)
Sentinel Wood Treating, Inc.	Ashland, MO	Ava, MO	OW	1	72	36
				1	72	42
		Calico, AR	OW	1	72	42
		Heber Springs, AR	OW	1	72	45
Shollenberger Wood Treating	Bernalilco, NM	Bernalilco, NM	COW	1	72	36
F. Bowie Smith & Son, Inc.			CO			
Smith, W. J., Wood Preserving Co.	Denison, TX	Denison, TX	CO	1	72	127
					72	147
				1	105	172
				2	96	150
Southern Wood Piedmont Company	Spartanburg, SC	Augusta, GA	CO	3	96	132
		Baldwin, FL	COW	1	96	132
				2	96	122
		Chattanooga, TN	C	2	96	106
				1	96	145
		East Point, GA	CO	1	96	145
				1	96	122
Southern Wood Piedmont Company (continued)		Gulf, NC	CO	1	72	142
				1	72	137
				1	72	88
				1	72	150
		Macon, GA	CO	1	84	106
				1	96	122
		Spartanburg, SC	COW	3	96	114
				2	96	125
				1	96	50
		Waverly, OH		2	96	145
		Wilmington, NC	CW	2	96	130
				1	72	130
		Prescott, AZ	OWG	1	96	90
Stallworth Timber Co., Inc.	Beatrice, AL	Beatrice, AL	CO	1	72	106
				1	72	50
Standard Wood Preservers of Shreveport, Inc.	Shreveport, LA	Shreveport, LA	CO	1	96	110
				1	96	107
				1	72	75
Steinkamp Warehouses, Inc.	Huntingburg, IN	Huntingburg, IN		1	72	42
St. Regis Paper Company	Cass Lake, MN	Cass Lake, MN	CO	1	72	125
				1	72	150
				2	72	100
Sumter Wood Preserving Co.			O			
John C. Taylor Lumber Sales	Sheridan, OR	Sheridan, OR	CO	1	72	110
				2	72	164
				1	76	164
TMA Forest Products Group	Lockhart, AL	Lockhart, AL	CO	1	72	90
				3	72	50
				1	72	40
Temple Eastex, Inc.	Diboll, TX	Diboll, TX	CO	2	96	85
Texarkana Wood Preserving Co.	Texarkana, TX	Texarkana, TX	CO	1	84	63
				2	72	110
Texas County Post Company, Inc.	Raymondville, MO	Raymondville, MO	O	1	72	36
				2	48	30
Texas Electric Cooperatives, Inc.[b]	Jasper, TX	Jasper, TX	C	1	96	110
				1	96	125
Unadilla Silo Co., Inc.	Unadilla, NY	Unadilla, NY	C	2		18
Virginia Wood Preservers Div., Rentokil, Inc.	Richmond, VA	Laurel, VA	COWF	1	72	56
				1	72	74
Walker-Williams Lumber Co., Inc.	Hatchechubbee, AL	Hatchechubbee, AL	OW	1	72	64
				1	72	60
				1	72	84
Watkins Lumber Co.	Albany, GA	Albany, GA		1	72	75
Webster Wood Preserving Co.	Wayzata, MN	Bangor, WI	C	2	96	100

(continued)

TABLE XXIII (concluded)

				Pressure cylinders		
Managing Company	Headquarters	Plant Location	Preservatives used[a]	No.	Dia. (inches)	Length (feet)
Western Tar Products Corp., The	Terre Haute, IN	Terre Haute, IN	COW	1	72	84
				1	72	96
				2	72	178
				1	72	150
Western Wood Preserving Co.	Summer, WA	Summer, WA	COWF	1	72	90
				1	72	145
Weyerhauser Company	De Queen, AR	De Queen, AR	OW	7	96	112
Wood Preservers, Inc.	Warsaw, VA	Warsaw, VA	COW	4	72	80
Wyckoff Company	Seattle, WA	Eagle Harbor, WA	CO	6	90	132
		Seattle, WA	COW	1	96	120
				1	30	45
				1	84	130
				2	96	132
				4	75	120
Total number of plants using organic preservatives = 206						

[a] Type of preservatives used:

C -- Creosote
O -- Oilborne
W -- Waterborne
F -- Fire retardant
G -- LP gas

[b] Noncommercial plants

TABLE XXIV. MATERIALS TREATED IN THE UNITED STATES BY PRESERVATIVE (1,000 m^3) (Reference 30)

Year	Creosote and creosote-coal tar	Creosote-petroleum	Creosote/penta	Total creosote	Petroleum penta
1953	5644	1776	--	7420	446
1954	4439	1590	--	6029	626
1955	4343	1421	--	5764	769
1956	4377	1396	--	5773	1031
1957	4744	1454	--	6198	1030
1958	3853	1124	64	5041	1033
1959	3209	999	219	4427	1109
1960	3289	968	215	4472	1142
1961	3304	867	250	4421	1166
1962	3119	803	282	4204	1291
1963	3213	772	318	4303	1252
1964	3465	890	311	4666	1399
1965	3702	969	285	4956	1547
1966	4069	853	284	5206	1816
1967	4146	1000	225	5371	1879
1968	3979	905	223	5107	1846
1969	3545	848	200	4593	1729
1970	3587	926	152	4665	1859
1971	3632	871	114	4617	1967
1972	3550	818	34	4402	2145
1973	3012	666	18	3696	2264
1974	3395	(D)	(D)	3395	(D)
1975	3126	907	25	4058	1720
1976	3061	849	23	3933	(D)
1977	3302	587	132	4021	1551
1978	3955	527	43	4525	1947

(D) = Data not shown to avoid disclosure of individual company data.

TABLE XXV. ESTIMATED MASS OF SELECTED POLLUTANTS CONTAINED IN WASTEWATER REQUIRING TREATMENT AND DISPOSAL (kg/year) (Base Year 1978)

	Benzene	Ethyl-benzl	Toluene	Phenol	Penta	Trichlorophenol
Penta						
Open steaming	836.3	514.6	1,001.7	19,528.4	22,009.7	180.1
Closed steaming	212.6	130.8	254.7	4,964.9	5,595.7	50.0
Boultonizing	N/A	N/A	N/A	19.2	2,949.9	N/A

	Naphthalene	Fluorene	Phenanturene/ anthracene	Pyrene	Fluoranthene
Creosote					
Open steaming	11,213.0	3,257.1	10,892.6	3,203.7	4,378.4
Closed steaming	2,850.8	828.1	2,769.3	814.5	1,113.2
Boultonizing	1,975.0	518.3	767.3	122.0	177.4

$$\text{Mass emission rate (kg/yr)} = \frac{\text{Wastewater generation rate (Tables VIII through X)}\ \frac{1}{m^3} * \text{Annual treated product (Table XXIV)}\ \frac{m^3}{yr}\ \text{Pollutant concentration (Tables XI through XVIII)}\ \frac{mg}{l}}{10^6}$$

N/A -- Not analyzed

SECTION 6

WASTE TREATMENT OR DISPOSAL TECHNOLOGY AND EMISSION CHARACTERIZATION

In wood preserving plants, wastewater generated by wood treating processes contains the largest amount of pollutants requiring disposal. To comply with zero pollutant discharge regulations, the wastewater is usually contained within the plant's boundaries. Reflecting the scope of work performed, this section presents options for wastewater disposal or treatment with emphasis on evaporation technology. Characterization, through field and laboratory test programs and theoretical model analysis, of evaporative technology and the emissions that ultimately escape control is presented in detail.

6.1 WASTEWATER TREATMENT

As discussed in Section 5.3, the wastewater that must be disposed of consists of process wastewater (water, wood extractives, preservatives, and oils), boiler blowdown, and plant runoff or rainwater. In general, the wastewater generated will vary in volume as well as content, depending on the treatment process and degree of dilution from other sources.

The design of a disposal system is dependent on the characteristics of the wastewater. Such wastewater typically contains free and emulsified oils, organic compounds, toxic materials, and heavy metals. A decrease in the volume of wastewater traditionally requiring disposal can be achieved and is quite cost effective. There are in-plant changes that can result in both a volume and pollutant burden reduction. These changes include:

- Closed Steaming -- The switch from open to closed or modified closed steaming can result in a large water volume reduction as well as a decrease in the formation of oil-water emulsions

- Separation of Effluent Streams -- When a plant uses more than one preservative it is necessary to keep the different effluent streams from these preservatives separate. This improves recovery of preservatives.

- Reuse of Cooling Water -- The recycling of cooling and process water, as opposed to treating it as waste, will reduce the volume of effluent. This is essential for plants using barometric condensers.

- Plant Sanitation -- Wastewater volumes can be reduced by eliminating leaks, spills, and drips from retort doors, and by segregating stormwater runoff and improving general plant maintenance

Subsequent to passing through any in-plant treatment, wastewater may be altered by a variety of treatment options. These are discussed in the following paragraphs.

Oil-Water Separators

Oil-water separators are extensively used in the wood preserving industry for the recovery of free oils. These vessels, typically designed following American Petroleum Institute (API) specifications, operate as gravity separators allowing for the less dense oil (with penta) to float to the surface and more dense creosote to settle and for the continuous removal of segregated liquids. To achieve maximum recovery of the free oil, the devices can be staged. Removal efficiencies of 60 to 95 percent can be achieved in a single stage (Reference 27).

Oil-water emulsions are not removed by the previously mentioned physical means; the emulsion must first be broken. Chemical flocculation has been a successful mechanism and involves the use of a flocculating agent such as metallic hydroxides, alum, ferrous salts, or large-molecular-weight polyelectrolytes (Reference 32). These agents cause a floc to form that may be separated by quiescent settling or filtration. Research performed by Dust and Thompson (Reference 32) indicated that the addition of lime produced the best floc formation and highest reduction in COD. The polyelectrolyte served to agglomerate the floc particles formed. This work further showed that flocculation also reduced penta concentrations contained in the wastewater. The reduction in penta levels is related to its slight solubility in water (Reference 33). Concentrations greater than 10 to 20 mg/l become associated with the entrained oils (Reference 34). During flocculation, the penta is removed along with the entrained oils. As shown in Table XXVI, lime flocculants did not reduce the phenol content, which has a higher solubility level.

Flocculation produces a sludge with a high oil and penta content. The sludge is typically dewatered and disposed of as landfill.

Other methods used to remove the oils is dissolved air flotation. Air under pressure is "dissolved" in the wastewater stream to the oil-water separator. When the pressure is released, the dissolved air forms bubbles which float the oils to the surface. This process would produce less sludge than flocculation processes.

Evaporation

Following free oil removal, a primary disposal option is to evaporate the remaining wastewater. Evaporation is a viable disposal option to reach zero discharge because of the relatively low volumes of wastewater generated at a typical plant. There are four types of evaporation techniques that are

TABLE XXVI. REDUCTION IN PHENOL AND PENTA CONTENT OF WASTEWATERS RESULTING FROM PRIMARY TREATMENTS WITH LIME (Reference 32)

Lime dosage (g/liter)	Phenol (mg/liter)	Penta (mg/liter)
0	83	150
0.25	81	--
0.50	72	--
0.75	78	--
1.00	80	45
1.25	84	
1.50	83	25
2.00	--	17

used: containment with solar evaporation, thermal evaporation, spray evaporation, and cooling tower evaporation. In a survey of 183 plants using pressure treating technology, 93 plants disposed of their accumulated wastewater by evaporation. Of this number, 39 used containment ponds, 16 used thermal evaporation, 30 used spray pond evaporation, and 8 used cooling towers.

Containment ponds are the most simple of the evaporation processes. The wastewater is pumped to a large pond and left to evaporate. For a containment pond to be successful, the evaporation rate must exceed the annual precipitation rate for that geographical area. While this system is simple to construct and operate, it does have a large land requirement.

Using a spray system decreases the land requirement for containment and the impact of climatic conditions. By forcing the water through spray nozzles, the resulting droplets generate a larger surface area which is exposed for evaporation. Pond size, and the location and number of spray nozzles are all determined by climatic conditions and volume of waste.

The evaporation process can be accelerated by directly applying heat to evaporate the water, as in a thermal (pan) evaporator. Here, the wastewater is piped to a vessel that uses an external heat source, such as boiler steam, to promote evaporation. This process is very energy-dependent and may therefore be used only to supplement other treatment methods, or when surges of wastewater require disposal of additional volumes. To reduce energy costs, waste or excess steam from the boilers may also be used. Another source of heat is the use of wastewater as condenser cooling water. Reportedly, wastewater can also be disposed of by direct venting from the retort. This should be applicable only to small water volumes.

The use of a cooling tower is still another means of evaporating wastewater; however, it is only applicable to Boulton conditioning/treating systems. As the water vapor from the retort is condensed, it gives up heat in the condenser. The condensed wastewater is accumulated, then sent to the oil-water separator. The effluent wastewater from the oil-water separator is added to the cooling water that recirculates through the condenser, then through the cooling tower. The waste heat promotes evaporation. In steaming plants, there is insufficient waste heat to evaporate the volume of wastewater generated.

The principal behind the evaporation of the wastewater is to dispose of the water fraction while leaving the organic constituent for subsequent recycling to the process or disposal. Since volatile and other low-molecular-weight organic constituents are present in the wastewater, the potential exists for the release of organic compounds to the atmosphere. The following discussion presents the results and data analysis of laboratory and field testing programs designed to characterize evaporation technology.

Surface Evaporation Emissions

While evaporative processes allow plant operators to achieve zero wastewater discharge, they are operated under the assumption that no organic compounds are transferred to the air. Under the assumption that organics are released, a program was undertaken to determine if pH adjustment of wastewater could hold the organics in the sludge fraction remaining following evaporation (see Appendix A for a complete discussion of the program and results). During the execution of this work, penta and creosote wastewater samples were to be obtained from Boulton conditioning wood treating process(es) after the oil-water separator and before any treatment process. The samples were acidified and basified using hydrochloric acid and sodium hydroxide, respectively. Quantitative chemical analysis of the wastewater charged to the evaporator was performed, followed by evaporation of the wastewater and sampling of the air emissions given off.

The results of the first set of material balance tests are shown in Table XXVII. Though the material balances do not show complete recovery of penta (most likely due to the design of the test apparatus -- see Appendix A), penta was emitted along with the water vapor and none was detected in the sludge fraction (residue). It should also be noted that the wastewater being treated contains very little penta in solution, less than the other wastewaters tested. To confirm the emission of penta in the air stream, a second apparatus was designed that would allow for more controlled evaporation and component recovery. In addition, the wastewater charge was filtered to remove the flocculated material that had formed following pH adjustment. The results of this series of tests are shown in Table XXVIII. Again, penta was emitted in the air stream. From this data, it can be seen that a smaller fraction of penta was emitted from the acidic solution. Since nearly total recovery of the penta occurred, it is expected that the penta was not chemically destroyed, but its evaporation was retarded (see analysis of results).

A third set of data describes the emission characteristics of the components of creosote. As shown in Table XXIX, the organic compounds present are also partially volatilized and emitted in the gas stream. However, unlike

TABLE XXVII. PAN EVAPORATION TESTS WITH PENTA WASTEWATER (mg)

				Elapsed time/XAD-2 penta concentrations					
Avg. temp. (^{o}C)	pH	Charge	Residue	0-1 hrs	1-2 hrs	2-3 hrs	3-4 hrs	Total emitted	Percent recovery
81.0	Unadj.	1.8	ND	0.3	0.5	0.3	--	1.1	61
76.3	10	1.8	ND	0.1	0.2	0.1	0.3	0.7	39
80.5	2	1.8	ND	0.2	0.2	0.1	--	0.5	28
88.2	12	1.8	ND	1.1	0.	0.35	0.1	1.2	67

ND = None detected
Volume of wastewater evaporated -- 2 liters

TABLE XXVIII. PAN EVAPORATION TESTS WITH PENTA WASTEWATER (mg)

						Elapsed time/XAD-2 penta concentration					
Avg. temp. (^oC)	pH	Charge	Filter cake	Residue	Water being evaporated	0-4 hrs	4-8 hrs	8-12 hrs	Total emitted	Percent emitted from water	Percent recovery
70	2	197	165	3	29.0	14	1.2	1.6	16.8	58	94
90	12	475	1.5	2.7	470.8	112	127	197	436	93	93

Volume of wastewater evaporated -- 1 liter

TABLE XXIX. PAN EVAPORATION TESTS WITH CREOSOTE WASTEWATER (mg)

						Elapsed time/XAD-2 component concentration						
Component	Average temperature (ºC)	pH	Charge	Filter cake	Residue	Water being evaporated	0-4 hrs	4-8 hrs	8-12 hrs	Total emitted	Percent emitted from water	Percent recovery
Naphthalene	70	10	27	--	0.05	26.95	16	4.1	6.1	26.2	97	97
	80	2	14	4.6	0.01	9.39	5.9	1.2	2.9	10.0	106	104
Acenaphthene	70	10	5.5	--	<0.01	5.5	1.9	0.04	<0.01	1.94	35	35
	80	2	4	1.3	<0.002	2.7	0.34	<0.002	<0.002	0.34	13	41
Fluorene	70	10	3.6	--	<0.01	3.6	0.57	0.04	0.11	0.72	20	20
	80	2	1.8	0.80	<0.002	1.0	0.10	<0.002	0.010	0.11	11	51
Phenanthrene/ Anthracene	70	10	1.6	--	<0.01	1.6	0.37	0.11	0.14	0.62	39	39
	80	2	0.6	0.48	<0.002	0.12	0.079	0.016	0.060	0.16	133	106

Volume of wastewater evaporated -- 1 liter

the penta, pH adjustment does not significantly impact the evaporation of the organics. This may be due to the basic differences between the structure of the compounds being evaporated. The evaporative mechanisms will be fully discussed following the development of the evaporation models.

Two posssible mechanisms could account for the emission of organics in the air stream; first, volatilization and emission of the organics from the wastewater as a result of thermal driving force, or second, the formation of aerosols during evaporation that are subsequently emitted from the evaporator.

The temperature of the evaporating wastewater was maintained below the boiling point of water, thereby reducing the possibility of splattering. Therefore, the first mechanism was expected to be the primary driving force for the loss of organic material to the air. To evaluate this mechanism further, a model was developed that would allow for the comparative analysis between the predicted and measured concentrations of organic species emitted.

The model for the evaporation rate of chlorinated phenolic and other organic chemical pollutants from the surface of wastewater evaporation systems (thermal ponds or pan evaporators) can be developed from Fick's first law of diffusion. The following qualifying assumptions must be made:

- The system is at steady state (i.e., the liquid is at equilibrium with the gas at the liquid surface)
- The wastewater is an ideal solution
- There is a stagnant layer of air above the pond
- The vaporized organic compound forms an ideal gas mixture with air
- The solubility of air in the wastewater is negligible
- Constant temperature and pressure in the stagnant air layer

With these assumptions, the minimum evaporation rate of each organic pollutant in the wastewater can be estimated from the product of the evaporation rate of the pure compound into stagnant air and the mole fraction of the pollutant in the wastewater. The model is presently assumed to be independent of the humidity of the air. Therefore, stagnant air will represent the maximum resistance to evaporation. The evaporation rate of each pollutant into stagnant air is equivalent to the mass flux of the pollutant from the surface of a pond of pollutant. This flux is calculated from the equation of mass flux, using the average concentration of pollutant in a region between $Z = Z_1$, and $Z = Z_2$ (see Figure 10).

The average concentration between $Z = Z_1$, and $Z = Z_2$ is obtained from the concentration profile derived as follows:

Fick's first law of diffusion, written in terms of molar flux (N_A) is:

$$N_A = -cD_{AB} \frac{\partial x_A}{\partial z} + x_A (N_A + N_B) \qquad (1)$$

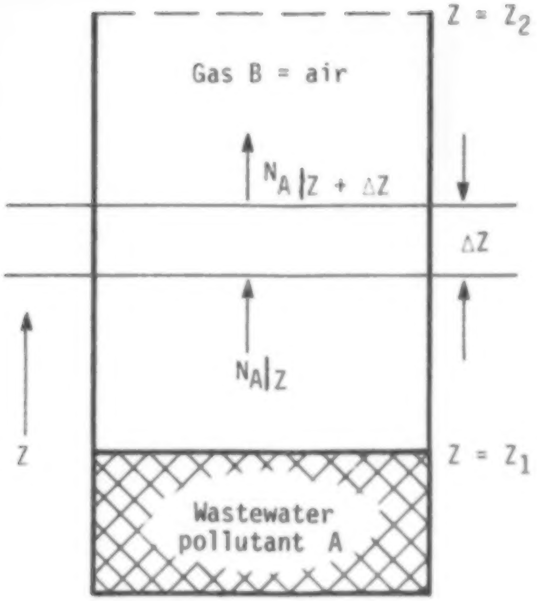

$Z = Z_2$
Gas B = air
$N_A|Z + \Delta Z$
ΔZ
$N_A|Z$
Z
$Z = Z_1$
Wastewater
pollutant A

Figure 10. Model for evaporation through a stagnant layer.

where

N_A = molar flux of species A into B in the z direction, g moles $L^{-2}t^{-1}$

c = total molar concentration, g moles L^{-3}

D_{AB} = binary diffusivity for system composed of species A and B, L^2t^{-1}

$\partial x_A/\partial z$ = The concentration gradient of species A, L^{-1}

N_B = molar flux of species B into A, g moles $L^{-2}t^{-1}$

Since the air is insoluble in the wastewater and the system is at steady state, the flux of the air into the liquid, N_B, is zero. Equation (1) for N_A then becomes:

$$N_A = \frac{-cD_{AB}}{1-x_A} \cdot \frac{dx_A}{dz} \tag{2}$$

At steady state, the flux of A throughout the stagnant layer is constant. Therefore:

$$\frac{dN_A}{dz} = 0 \tag{3}$$

For ideal gas mixtures at constant T and P, c is a constant and D_{AB} is nearly independent of concentration and, therefore, independent of Z. Equations (2) and (3) can the be combined to yield:

$$\frac{d}{dZ} \quad \frac{1}{1-x_A} \; \frac{dx_A}{dz} = 0 \tag{4}$$

Equation (4) can be integrated and the constants of integration evaluated from the boundary conditions at the liquid surface and at the top of the stagnant layer given by:

$$\begin{aligned} X_A &= X_{A_1} \text{ at } Z = Z_1 \\ X_A &= X_{A_2} \text{ at } Z = Z_2 \end{aligned} \tag{5}$$

This results in expressions for the concentrations X_A and X_B given by:

$$\left(\frac{1-x_A}{1-x_{A_1}}\right) = \left(\frac{1-x_{A_2}}{1-x_{A_1}}\right)^{\left(\frac{z-z_1}{z_2-z_1}\right)} \tag{6}$$

$$\left(\frac{x_B}{x_{B_1}}\right) = \left(\frac{x_{B_2}}{x_{B_1}}\right)^{\left(\frac{z-z_1}{z_2-z_1}\right)} \tag{7}$$

The rate of evaporation at the liquid surface ($z=z_1$) is obtained by combining Equations (2) and (6).

$$N_A \bigg|_{z=z_1} = \frac{cD_{AB}}{(z_2-z_1)} \cdot \ln\left(\frac{1 - X_{A_2}}{1 - X_{A_1}}\right) \tag{8}$$

This equation may also be expressed in terms of total and partial pressures:

$$N_A \bigg|_{z=z_1} = \frac{P_T D_{AB}/RT}{\left(z_2 - z_1\right)} \cdot \ln\left(\frac{P_T - P_{A_1}}{P_T - P_{A_2}}\right) \tag{9}$$

where

P_T = total pressure, atm

P_A = partial pressure of species A, atm

R = gas constant, 82.05 cm^3 atm $gmole^{-1}$ $^oK^{-1}$

T = ambient air temperature, ^oK

$z_2 - z_1$ = film thickness, cm

Equation (9) describes the mass transfer rate, or evaporation rate of liquid A into gas B.

In estimating the evaporation rate of organic vapors into air (simulating the laboratory apparatus described on page A-27), it is assumed that the diffusion layer z_2-z_1 is 2 cm thick and that the air is stagnant and insoluble in the organic compound within that layer. It is also assumed that the ambient pressure is 760 mm Hg (1 atmosphere).

From these assumptions, the previous equation becomes:

$$N_A = \frac{1 \text{ atm } D_{AB}}{\left(83.05 \frac{\text{atm - cm}^3}{\text{g mole cm } ^oK}\right)T} \cdot \frac{1}{2 \text{ cm}} \ln\left(\frac{1 - P_{A2}}{1 - P_{A1}}\right) \tag{10}$$

$$= \frac{6.02 \times 10^{-3} D_{AB}}{T} \quad \ln\left(\frac{1 - P_{A2}}{1 - P_{A1}}\right)$$

This equation gives the evaporation rate for a compound with a given diffusivity and temperature in gram moles per cm^2 per second.

In many cases, the diffusivity and vapor pressure of the organic compound in air was not readily available in the literature. In these instances, the following equations were used (Reference 73):

$$D_{AB} = \frac{2.745 \times 10^{-4}}{P} \left(P_{cA} \cdot P_{cB}\right)^{1/3} \left(T_{cA} \cdot T_{cB}\right)^{5/12} \left(\frac{1}{M_A} + \frac{1}{M_B}\right)^{1/2} \left(\frac{T}{\sqrt{T_{cA} T_{cB}}}\right)^{1.823} \tag{11}$$

where

$P_{cA,B}$ = critical pressure, atm

$T_{cA,B}$ = absolute temperature, ^{o}K

$M_{A,B}$ = Molecular weights of components A and B

D_{AB} = diffusivity, cm^2/s

If the diffusivity at one temperature was known, the diffusivity at other temperatures can be estimated as follows:

$$D_{AB_T} = D_{AB_{T_o}} \left(\frac{T}{T_o}\right)^{1.823} \tag{12}$$

Vapor pressures were estimated by a method proposed by Riedel (Reference 36).

$$\ln P_{vp_r} = A - \frac{B}{T_r} + C \ln T_r + D T_r^{6} \tag{13}$$

The constants in this equations are given by:

$A = -35Q$
$B = -36Q$
$C = 42Q + \alpha_c$
$D = -Q$
$Q = 0.0838\ (3.758 - \alpha_c)$

$$\alpha_c = \frac{0.315\Psi_b + \ln P_c}{0.0838_{\ b} - \ln T_{b_r}}$$

$$\Psi_b = -35 + \frac{36}{T_{b_r}} + 42 \ln T_{b_r} - T_{b_r}^{6}$$

In these equations, T_c and P_c are the critical temperature and pressure, respectively, T_{b_r} is the reduced boiling point, T_b/T_c, and P_{vp_r} is the reduced vapor pressure, P_{vp}/P_c. This equation gives the vapor pressure in atmospheres. If not available in the literature, critical properties of an organic compound may be estimated by methods presented in Perry's Chemical Engineer's Handbook.

The diffusivity and vapor pressures calculated from these equations can be used in estimating the evaporation rate of a pure organic liquid into air. This procedure would be applicable if the organic constituents formed a layer over the wastewater. To estimate the evaporation rate of an organic liquid from an aqueous solution (emulsion), it is assumed that the organic compound forms an ideal solution with water, and that its vapor forms an ideal mixture in air. The evaporation rate of the organic from the solution then, is given by the product of the pure liquid evaporation rate and the mole fraction of organic in the wastewater.

Test and Model Results

Table XXX presents values and predicted evaporation rates for several pure organic constituents found in wood treating wastes. The evaporation rates for penta and naphthalene are presented in Figures 11 and 12. To compare the actual, measured emissions of organic constituents from wastewater to the model, Table XXXI was generated. This table compares the gram moles of organic (naphthalene or penta) emitted per hour per square meter of liquid surface area. Inspection of this table and Figure 13 clearly shows that organics are volatilized at a greater rate than would be predicted. The impact of the solution pH is not apparent, indicating that filtration must follow pH adjustment to effect control over organic evaporation. Clearly, another strong driving force for evaporation is affecting this process.

The product of the pure liquid evaporation rate and the mole fraction of the organic compound in the wastewater is a form of Raoult's Law, and without evaporation rate constants, is expressed by:

$$P_i = P_i^* x_i \tag{14}$$

where

P_i = partial pressure of the ith component over liquid solution

P_i^* = partial pressure of the ith component over pure component i

x_i = mole fraction of ith component in solution

The use of Raoult's Law is based on two assumptions, ideal gas behavior of the vapor state, and ideal solution behavior of the liquid state. These are the bases for the theoretical calculations of Tobiason (Reference 74). It becomes imperative to examine the underlying definitions and limits to these assumptions to verify the theoretical validity or appropriately modify our model.

A perfect gas mixture is defined thermodynamically by the equation:

$$\mu_i^{vap} = \mu_i^o + RT \ln p_i \tag{15}$$

where

μ_i^{vap} = the chemical potential of the ith component

μ_i^o = the portion of the chemical potential of the ith component that is dependent on temperature only

TABLE XXX. THERMAL POND EVAPORATION

	Temperature			Critical pressure			
Pollutant	T (^oC)	$T_{boiling}$ (^oK)	$T_{critical}$ (^oK)	$P_{critical}$ (atm)	Diffusivity (cm^2/s)	Vapor pressure (mm Hg)	Predicted evaporation rate of a pure solution (g/hr m^2)
Benzene	0	353.2	562.1	47.7	0.077	27.34	188.0
	10				0.082	46.59	314.0
	20				0.087	76.20	537.0
	30				0.093	120.15	903.0
	40				0.098	183.28	1450.0
Toluene	0	383.8	591.7	41.6	0.076	6.63	49.0
	10				0.081	12.16	93.0
	20				0.086	21.25	168.0
	30				0.091	35.93	293.0
	40				0.96	57.97	494.0
Phenol	0	455	694.2	60.5	0.016	0.062	0.10
	10				0.018	0.151	0.25
	20				0.019	0.345	0.59
	30				0.020	0.738	1.3
	40				0.021	1.495	27.0
Naphthalene	0	483.1	748.4	40.0	0.051	0.036	0.25
	10				0.055	0.084	0.60
	20				0.058	0.183	1.34
	30				0.062	0.377	2.85
	40				0.066	0.740	5.75
Penta	0	583	804.03	22.86	0.0092	3.6×10^{-5}	7.86×10^{-5}
	10				0.0098	1.23×10^{-4}	2.8×10^{-4}
	20				0.0105	3.85×10^{-4}	1.05×10^{-3}
	30				0.011	1.108×10^{-3}	2.7×10^{-3}
	40					2.96×10^{-3}	7.3×10^{-3}

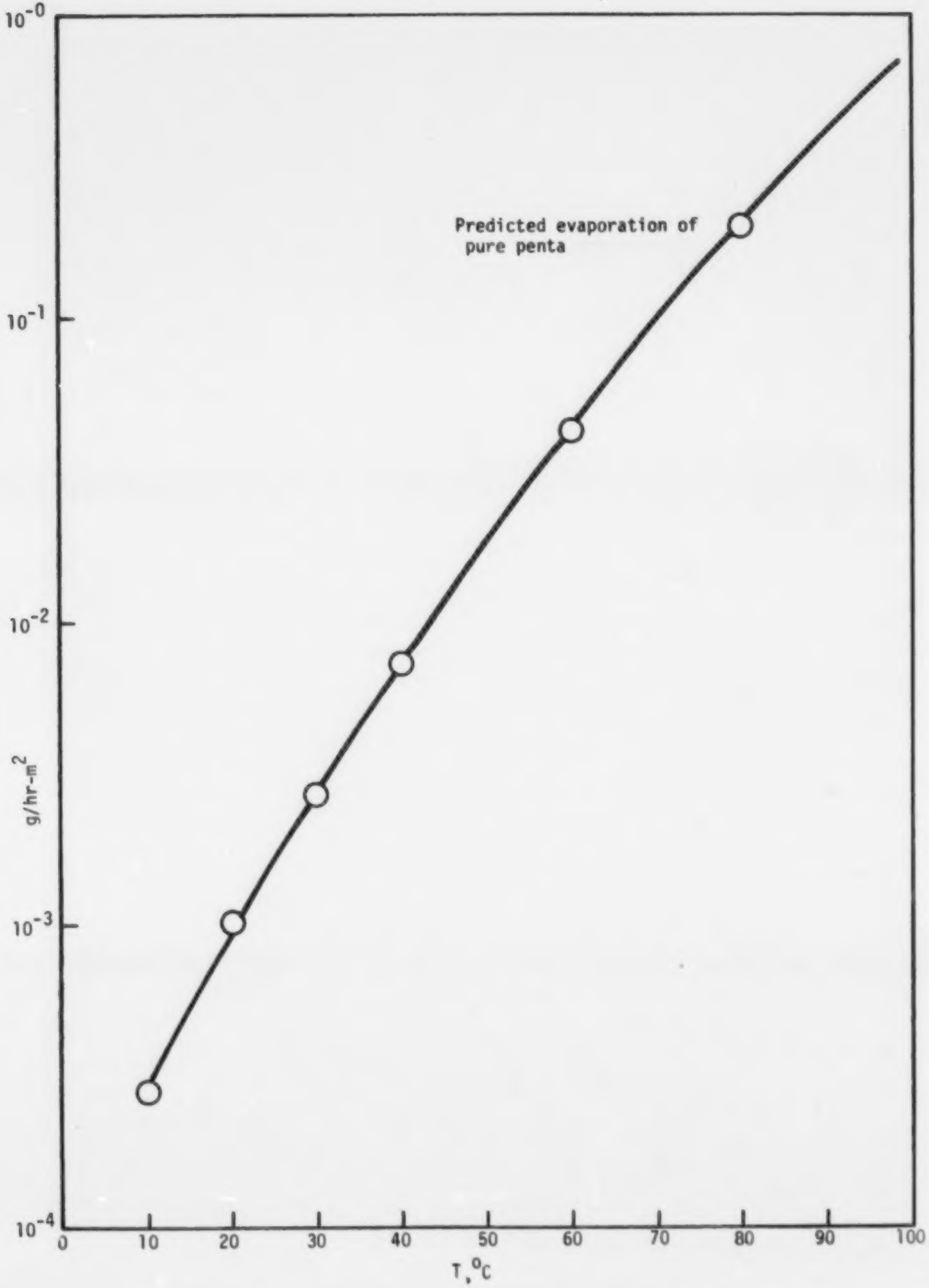


Figure 11. Predicted evaporation rate of pure penta as a function of temperature.

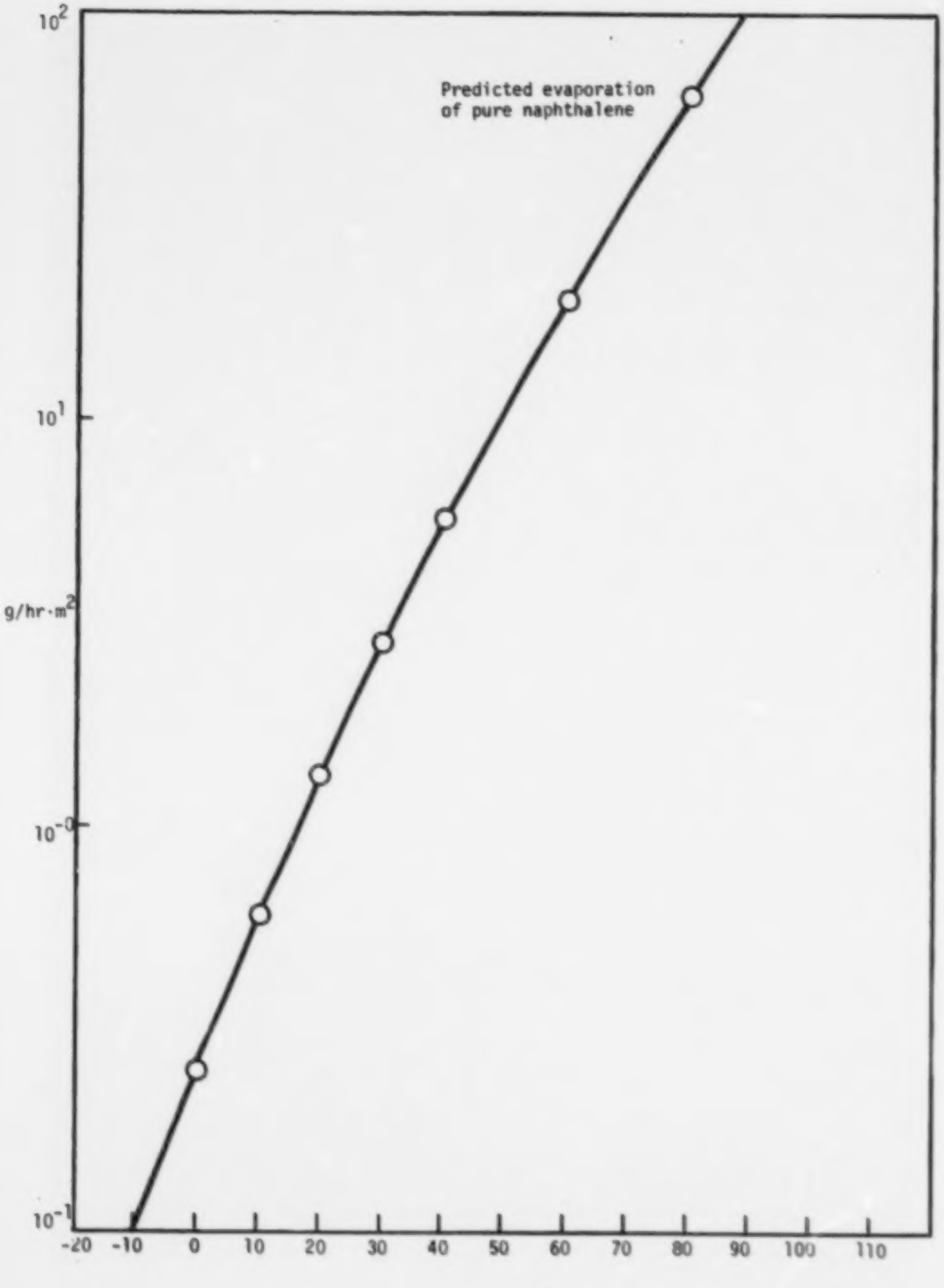


Figure 12. Predicted evaporation rate of pure naphthalene as a function of temperature.

TABLE XXXI. COMPARISON BETWEEN PREDICTED AND MEASURED EVAPORATION RATES

	Temperature (°C)	Solution pH	Predicted gmoles/hr-m^2	Measured gmoles/hr-m^2
Naphthalene	70	10	1.15×10^{-5}	2.04×10^{-3} 5.23×10^{-4} 7.78×10^{-4}
	80	2	1.07×10^{-5}	7.52×10^{-4} 1.53×10^{-4} 3.70×10^{-4}
Penta	70	2	5.28×10^{-8}	8.59×10^{-4} 7.36×10^{-5} 9.82×10^{-5}
	90	12	5.36×10^{-7}	6.87×10^{-3} 7.79×10^{-3} 1.21×10^{-2}

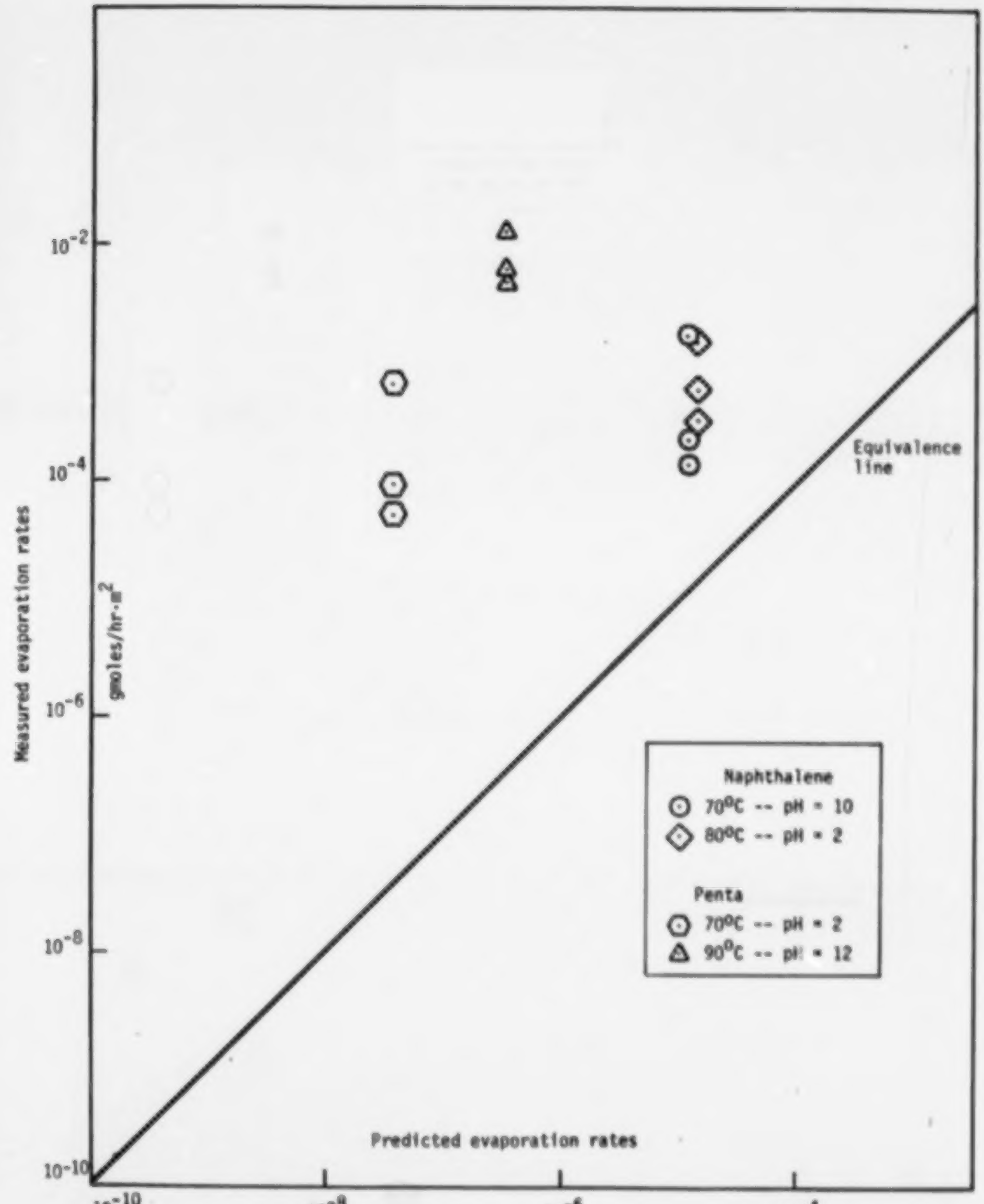


Figure 13. Relationship between measured and predicted evaporation rates.

Similarly, for a perfect solution:

$$\mu_i^{soln} = \mu_i^o + RT \ln p_i \qquad (16)$$

because, by definition, at equilibrium

$$\mu_i^{soln} = \mu_i^{vap} \qquad (17)$$

This leads to the imperical partial pressure curve for a binary solution shown in Figure 14. This is a direct result of Raoult's Law and is the exception rather than the rule (Reference 36). It is a reasonable approximation only when the components are very similar in molecular structure. The usual cases (exhibiting either positive or negative deviations) are illustrated in Figure 15.

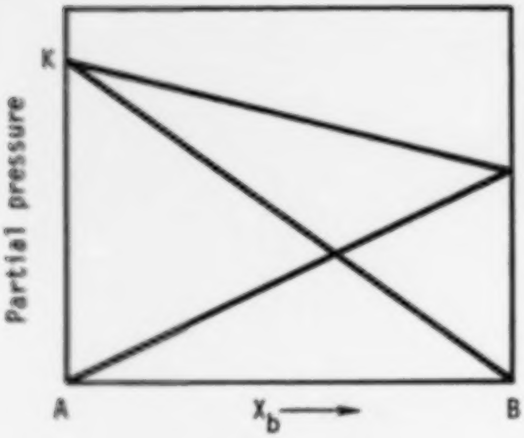
Positive deviation is the more common in organic mixtures, and is carried by detailed thermodynamic consideration at the molecular level. Phenolic-water systems are known to have positive deviations (Reference 74). The following paragraphs describe a case similar to the penta-water system taken from a study by Denbigh (Reference 36).

Incompletely Miscible Liquids

Molecular considerations indicate that positive deviations from Raoult's law may be expected to occur when the interaction energy between an A and a B molecule is smaller than the mean of the interaction energy of A with itself and of B with itself. For example, in the case of a dilute solution of A in B, if the B-B interaction is larger than the A-B interaction, the "escaping tendency" of the substances A will be enhanced and its partial pressure over the solution will be greater than expected according to Raoult's law.

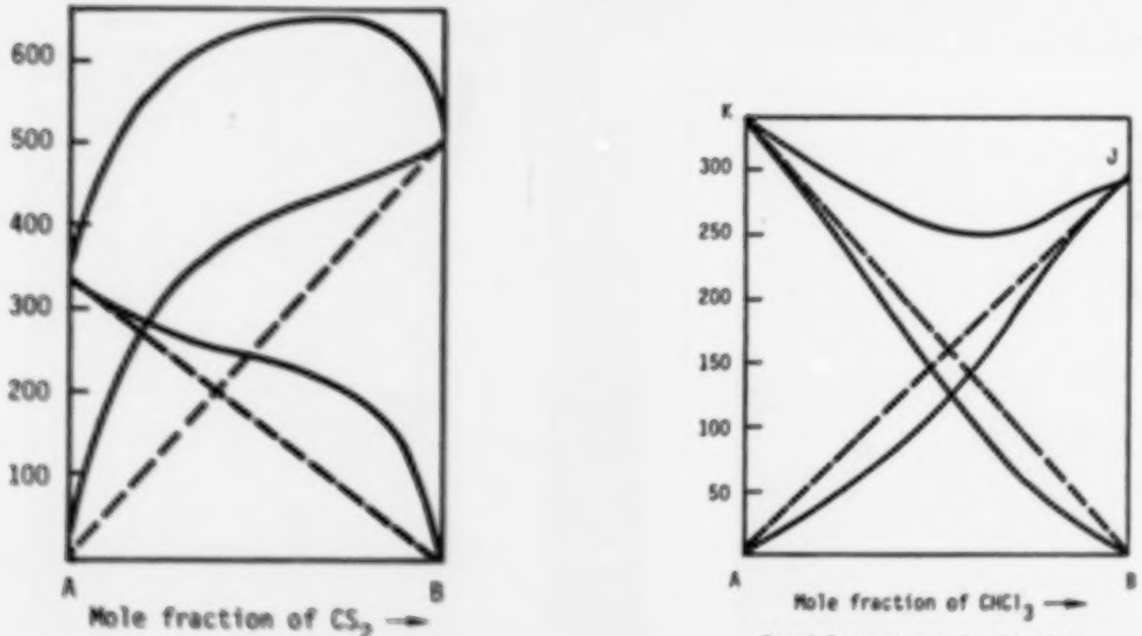
When positive deviations from Raoult's law reach a certain point (at which the A-A and B-B interactions are large compared to the A-B interactions) the system may break down into two liquid layers, one containing an excess of A and the other containing an excess of B. When these layers are in equilibrium, they are called conjugate phases. In both layers the chemical potential of a particular component is, of course, the same and also its partial pressure. For example, at 25°C a mixture of water and benzene consists of two liquid phases, one containing about 0.07 percent of water and the other containing 99.9 percent of water. The partial pressure of water over both of these solutions is the same; similarly the partial pressure of benzene is the same for each.

Typical partial pressure curves of a system of this type are shown in Figure 16. The dotted straight lines AJ and BK represent Raoult's law, if it were applicable. Any mixture of overall composition lying between LM and NP consists of the two liquid layers of compositions L and N, respectively (and it can be proved that a mixture of overall composition corresponding to the



Partial vapor pressures
of ideal solution

Figure 14. Partial vapor pressures of ideal solution.



Partial pressures in the mixture
carbon disulphide-acetone at 35.2°C.

Positive Deviation

Partial pressures in the mixture
acetone-chloroform at 35.2°C.

Negative Deviation

Figure 15. Incompletely miscible liquid partial vapor pressure deviation from Raoult's law ideal solution.

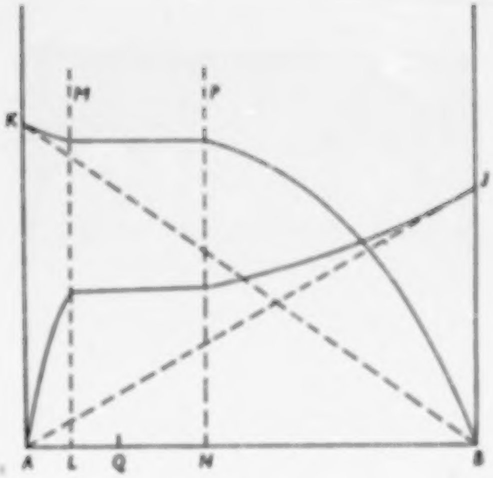


Figure 16. Partial pressures of a pair of partially miscible liquids.

point Q consists of the phases of compositions L and N in the molar ratio QN:QL, respectively).

Briefly, then, a solution of penta in water should have a partial pressure higher than that predicted by Raoult's Law and constant over the range where penta exists in a separate phase in the water system. This problem is addressed by the introduction of the activity coefficient γ_i, which is a function of the molecular interaction in the solution. The original equations are thus changed to:

$$\mu_i^{soln} = \mu_i^o + RT \ln \gamma_i x_i \tag{18}$$

and

$$p_i = p_i^* \gamma_i x_i \tag{19}$$

The activity coefficient γi is thus a measure of the deviation from Raoult's Law and $\gamma_i < 1$ for positive deviation. A detailed and rigorous treatment is provided by Prigogine and Defay (Reference 37).

The effect on evaporation rates for environmental samples has been discussed by Mackay and Wolkoff (Reference 38), and is known industrially as "codistillation." For DDT, as an example, Acree (Reference 39) found that even though the ratio of DDT to water in the vapor phase formed on evaporation was small, it was much greater than the ratio in the liquid phase.

Therefore, it is expected that the predicted evaporation rates in the model based on Fick's Law of Vaporization are low, potentially by several orders of magnitude.

Using the Prigogine model (Reference 37) for regular solutions (the first order of correction to the ideal solution), an order of magnitude value for the activity coefficient of penta can be approximated. For regular solutions, Prigogine gives:

$$RT \ln \gamma_A = v_A^0 \left(\frac{v_B^0 \eta_B}{v_A^0 \eta_A + v_B^0 \eta_B} \right)^2 \left(\delta_A - \delta_B \right)^2$$

$$RT \ln \gamma_B = v_B^0 \left(\frac{v_B^0 \eta_B}{v_B^0 \eta_B + v_A^0 \eta_A} \right)^2 \left(\delta_B - \delta_A \right)^2 \qquad (20)$$

where

$$\delta_A = \left(\frac{\Lambda_A}{v_A^0} \right)^{1/2}$$

$$\delta_B = \left(\frac{\Lambda_B}{v_B^0} \right)^{1/2}$$

and

$\Lambda_{A,B}$ = molar heat of vaporization of specie A or B

$v_{A,B}^0$ = molar volume of specie A,B

$\eta_{A,B}$ = moles of specie A,B

The solubility of penta in water at 30^0 is approximately 80 mg/l or 5.4×10^{-3} moles/mole (Reference 75). The density of penta is 1.978 g/ml. Converting to a mole fraction basis, the information is shown in Table XXXII.

TABLE XXXII. MOLECULAR AND ACTIVITY COEFFICIENTS FOR WATER AND VARIOUS PHENOLS

	MW	Molar volume v^0 (1/mole)	Molar quantity n (moles)	Molar heat of vaporization λ (cal/mole)	Solubility parameter δ $(cal/l)^{1/2}$	Activity coefficient γ
Water	18	0.018	1	1.04×10^4	760	1
Penta	266	0.135	5.4×10^{-6}	1.03×10^4	348	$> 10^{16}$
Phenol	94	0.0877	1.28×10^{-2}	1.53×10^4	418	$> 10^6$
Cresol	138	0.126	1.96×10^{-3}	1.55×10^4	351	$> 10^{15}$

This shows that under the assumption of regular solution behavior (as opposed to ideal solution), the activity coefficient for these compounds will be much greater than one. This theoretical approximation is supported by empirical evidence. Several authors have reported the almost quantitative recovery of penta at the ppb level from water solutions by steam distillation. In addition, evaporation from ponds have been identified as the major source of airborne PAH's (References 38, 40, 41 and 43).

In summary, theory and experience support the results that organic material is stripped from water solutions at a much higher rate than is predicted simply by its pure vapor pressure. In fact, the prediction should be that the transfer of penta organics from water solutions to the atmosphere will be controlled by their rate of diffusion in water.

Several conclusions can be drawn from this discussion and data presentation:

- Organic compounds, including penta, naphthalene, phenol, and similar molecular weight substances, can be volatilized and discharged to the atmosphere during evaporation of water, or at lower than expected temperatures based solely on vapor pressures
- Adjustment of the pH and filtering the wastewater prior to evaporation can remove significant quantities of organic material that might otherwise be emitted into the atmosphere (Tables XXXVII through XXXIX)
- Reductions in the liquid temperature can reduce the volitalization of the organics by three orders of magnitude, indicating that solar evaporation ponds ($T < 35^0C$) may result in significantly less emissions. A solar pond was not tested during this program.

It must be noted that this discussion is based on the evaporation of an emulsion, with the organic constituents evenly dispersed throughout the wastewater. Since the predicted evaporation rate is impacted by the concentration of the organics in solution, if free oils containing the preservatives float to the surface, the concentration of preservative in solution can be increased by several orders of magnitude, approaching the evaporation rates for the pure substances. Therefore, it is imperative that the primary oil-water separator be operated in its most efficient capacity to remove all free oils.

Droplet Evaporation Emissions

A second test program was undertaken to determine if organic compounds were emitted from a cooling tower. The cooling tower operates by exposing the surface of water to air, thus creating the necessary conditions for evaporation of organics. A Boulton drying process was identified and a test program initiated as described in Appendix B. The sampling and analytical methods used during the pan evaporation test series were also used for this program. The results of the emissions tests are presented in Table XXXIII. In this test series, it is seen that phenol, the lowest molecular weight compound present, was emitted from the tower. In addition, no phenol accumulations have occurred in the tower sump, indicating that the material vaporizes at the same rate it enters the system.

The rate of evaporation of chlorinated phenolics and other compounds from a droplet of wastewater can be estimated from an equation for the evaporation rate of a free falling drop. It must be assumed that the evaporation rate is small and therefore the velocity and concentration profiles are not distorted and the mass transfer coefficient is independent of mass transfer rate.

The mass transfer coefficient is defined in terms of the rate of diffusion of liquid into the gas normal to the interface:

$$J_{lia} = K_x \, \Delta x_A \tag{21}$$

where

K_x = mass transfer coefficient

x_A = vapor pressure of liquid A

In terms of molar flux this equation becomes:

$$N_{A_o} - x_{A_o} (N_{A_o} + N_{B_o}) = K_x \Delta x_A \tag{22}$$

If we define W_A and W_B to be the molar rates of transfer of A and B to the stream over the entire surface of the drop, then:

$$W_A - x_{A_o}(W_A + W_B) = k_x A \Delta x_A \tag{23}$$

TABLE XXXIII. COOLING TOWER ANALYTICAL RESULTS

					Concentration[a]		
I.D. no.	Sample		Description		Penta	TCP[b]	Phenol
79-2594	Feed 1	0-4 hrs	Test Day 1	5/22/79	810	75	< 1
79-2595	Feed 1	4-8 hrs	Test Day 1	5/22/79	1000	130	< 1
79-2596	Reflux	0-4 hrs	Test Day 1	5/22/79	1100	90	< 1
79-2597	Reflux	4-8 hrs	Test Day 1	5/22/79	1300	120	< 1
79-2598	Sludge	0-4 hrs	Test Day 1	5/22/79	28	0.8	< 0.1
79-2600	4HA-XAD-2	0-4 hrs	Test Day 1	5/22/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0042
79-2601	4HB-XAD-2	4-8 hrs	Test Day 1	5/22/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0038
79-2602	8H-XAD-2	0-8 hrs	Test Day 1	5/22/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0054
79-2626	Feed 1	0-4 hrs	Test Day 2	5/23/79	790	65	< 1
79-2627	Feed 1	4-8 hrs	Test Day 2	5/23/79	1000	80	< 1
79-2628	Reflux	0-4 hrs	Test Day 2	5/23/79	1400	160	< 1
79-2629	Reflux	4-8 hrs	Test Day 2	5/23/79	1000	90	< 1
79-2632	4HA-XAD-2	0-4 hrs	Test Day 2	5/23/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0029
79-2633	4HB-XAD-2	0-8 hrs	Test Day 2	5/23/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0028
79-2634	8H-XAD-2	0-8 hrs	Test Day 2	5/23/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0028
79-2658	Feed 1	0-4 hrs	Test Day 3	5/24/79	1000	80	< 1
79-2659	Feed 1	4-8 hrs	Test Day 3	5/24/79	780	85	< 1
79-2660	Reflux	0-4 hrs	Test Day 3	5/24/79	1200	110	< 1
79-2661	Reflux	4-8 hrs	Test Day 3	5/2479	630	65	< 1
79-2664	4HA-XAD-2	0-4 hrs	Test Day 3	5/24/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0026
79-2665	4HB-XAD-2	4-8 hrs	Test Day 3	5/24/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0028
79-2666	8H-XAD-2	0-8 hrs	Test Day 3	5/24/79	$< 5 \times 10^{-5}$	$< 5 \times 10^{-5}$	0.0027

[a] Units of concentration for: XAD-2 cartridges mg/m^3; sludge mg/g (wet weight) waters mg/l

[b] Trichlorophenol

where

W_A = transfer rate of A into B

with

A = wastewater component

B = air

k_x = mass transfer coefficient

x_A = vapor pressure of the liquid

A = drop surface area

If it is further assumed that the solubility of air in the wastewater is negligible, then $W_B = 0$. Therefore, solving for the evaporation rate of species A into air,

$$W_A = \frac{k_x A \Delta x_A}{1 - x_A} \tag{24}$$

Also, the mass transfer coefficient is expressed as:

$$\frac{k_x D}{C_f D_A} = 2.0 + 0.60 \left(\frac{D V_\infty \rho_f}{M_f}\right)^{1/2} \left(\frac{M_f}{\rho_f D_f}\right)^{1/3} \tag{25}$$

where

M_f = viscosity of air

ρ_f = density of air = 1.12×10^{-3} g/cc

V_∞ = velocity of droplet (assume terminal velocity)

c_f = g mole/cc molar conc. of air = 3.88×10^{-5} g mole/cc

D = droplet diameter

Rearranging, and substituting equation 25 into equation 24, a workable solution for the evaporation rate of organics from droplets is obtained.

$$W_a = \frac{\pi D C_f D_a}{4} \cdot \frac{x_{a_0} - x_{a_\infty}}{1 - x_{a_0}} \left[2.0 + 0.60 \left(\frac{D V_\infty \rho_f}{M_f}\right)^{1/2} \left(\frac{M_f}{\rho_f D_f}\right)^{1/3} \right. \qquad (26)$$

Using equation (26) and droplet parameters as shown, Table XXXIV was developed. It is interesting to note that the evaporation rate of the organic materials does not increase with increasing temperature driving force. Since the transfer coefficient includes the effects of the air surrounding the droplet, it is expected that the air increases in resistance to mass transfer over the temperature range of interest.

During execution of the Acurex test program on the cooling tower, the temperature differential between the reflux water and gas stream was less than 5°F. The emission rate of phenol was 7.17×10^{-5} g mole/min. The tower circulated approximately 1,000 gal/min (3.8 m^3/min) of wastewater. Based on 5,000 micron free falling drops, a free fall velocity of 30.5 m/sec and free fall distance of 5m, it is estimated that 160 drops would be available for evaporation at any instance in time. The total estimated evaporation rate from the tower is 1.9×10^{-6} g moles/min.

This estimated evaporation rate is low compared to the measured evaporation rate, as shown in Table XXXIV. Since each drop consists of an organic in water, Raoult's theory of the thermodynamics of evaporation will also apply in this case. In addition, the evaporation rate of penta is predicted to be 10^{-8} gmoles/min, well below the detection limit of the analytical methods.

Several conclusions can be drawn from this effort:

- Low-molecular-weight compounds can be emitted to the atmosphere from a cooling tower
- Phenol is emitted at the same rate that it enters the tower, hence the lack of accumulation of material
- The molecular weight of chlorinated phenols is sufficiently high that they were not volatilized

As described earlier, cooling towers are typically only applicable to processes using Boulton drying. Employing the droplet evaporation mechanism on processes using steam conditioning would require the use of a spray pond or similar gas/liquid contacting mechanism. Though a field test program to quantify organic emissions has not been conducted, it is expected that organic emissions may be higher than those for cooling towers. This is based on the following considerations:

- Forced ejection of the liquid, resulting in the generation of larger surface areas for evaporation

TABLE XXXIV. EVAPORATION RATE OF ORGANIC MATERIAL FROM A FREE FALLING DROP (g moles/min)

	Temperature differential (°F)/evaporation rates		
Compound	15	25	40
Phenol	1.18×10^{-8}	1.18×10^{-8}	1.17×10^{-8}
Toluene	2.83×10^{-6}	2.81×10^{-6}	2.80×10^{-6}
Benzene	1.14×10^{-5}	1.14×10^{-5}	1.14×10^{-5}

$v = 30.5$ m/second, $D = 5{,}000\ \mu m$

- High potential for drift (carryover of droplets from the pond by the wind)

Analysis of Results

Temperature, pH, and solution matrices will affect the emission of organic pollutants during various types of evaporation. For the purpose of clarity, two different types of organic pollutants must be considered: those having pH sensitive functionality (e.g., penta), and those without such functionality (e.g., PAH's). Volatilization of the nonreactive (to pH) constituents will be most affected by temperature and solution matrix and should be inversly proportional to size or molecular weight. For compounds containing pH sensitive functionality, pH and matrix effects will dominate.

With respect to pollutants without functional groups, as the molecular weight increases, both vapor pressure and solubility in water decrease. Thus, the heavier materials will be forced out of solution onto any particulate material in the liquor matrix. This is strongly supported by the creosote pan evaporator tests (Table XXIX) in the case of all the high-molecular-weight materials (above naphthalene) at both high and low pH, greater than 80 percent of the recovered material was found in the original filter cake. It was not in solution, but adsorbed on the particulate material. This effect should be enhanced by liquor matrices with a high ionic strength ("salting out"). On the other extreme, the low-molecular-weight materials, with higher solubilities and higher vapor pressures, tend to be liquid, will come out of solution as a surface layer, and be evaporated into the atmosphere. In complex mixtures, seen in the wood preserving industry, organic surface layers will tend to sorb and solubilize the high-molecular-weight compounds, increasing their volatilization potential.

Penta and other phenolic compounds are pH sensitive. The physical processes involved during evaporation of liquor containing these materials is more complicated. Using penta or the model compound, it can be considered to exist in at least five forms in the liquor.

- Chemically bound to particulate material
- Adsorbed on the surface of particulate material
- Phenolate ion in solution
- Molecular penta in solution
- A liquid phase suspended in or on the surface of the liquor

The concentration distribution of these forms at the beginning of any evaporation process will be highly dependent on pH and matrix. For the sake of clarity, the chemically bound form will be ignored in the following discussion.

Under low pH conditions, penta will be primarily in the molecular form, as a saturated solution in the liquor, adsorbed on particulate, and as a "pure" liquid phase. During evaporation of the liquor and according to the model put forth previously in this section, it should be rapidly volatilized, and the rate of volatilization should be dependent on the diffusion rate in water. This is qualitatively demonstrated in Table XXVIII (70°C test), where approximately 85 percent of the original penta was removed during preliminary filtration and 50 percent of the remaining (in solution) material was volatilized during the first 4-hour evaporation period.

Conversly, at high pH, the material should be primarily in solution in the ionic form with a very small quantity in molecular form (10^{-8}). Looking at a simplistic system and making some gross qualitative assumptions, a startling conclusion is reached. Assume:

- A batch solution of penta at pH 12 and concentration approximately 1 g/l

- No water is added to the solution as it is allowed to evaporate

- Molecular diffusion rates in the liquid are approximately constant over the range of temperatures under study

The following phases in the evaporative process will be observed:

- At the start of evaporation, the penta in the molecular form near the surface will be evaporated at a faster rate than the water

- As the molecular form is depleted, it will be made up by the ion-molecular equilibrium until all forms of penta near the surface are depleted. The system becomes diffusion dependent.

One more assumption is needed for the final conclusion. Assume that at some water evaporation rate the penta deficient layer of water is evaporated faster than the diffusion rate of penta into the layer. The volatilization of penta will become dependent upon the overall concentration of penta and remain (fairly) constant. Thus:

- At low water evaporation rates, the volatilization of penta will be diffusion dependent, but essentially all the penta should be volatilized

- At high water evaporation rates, penta will be volatilized at rates dependent on its bulk concentration and activity, but only that quantity that can vaporize before salt precipitation, phase separation, or other physical processes occur removing it from solution will escape

These effects are qualitatively seen in Table XXVIII (90°C test). At high pH (12) and high temperature, the penta is continually volatilized until complete evaporation has occurred.

Other Wastewater Treatment Technologies

Other wastewater treatment technology is also available and used by the industry, especially when discharging to POTW's is practiced. These treatment techniques are briefly presented here for continuity. The reader is referred to Reference 27, "Development Document for Effluent Limitations Guidelines and Standards for the Timber Products Processing Paint Source Category" for a more complete discussion.

Biological Treatments

Biological treatments of waste effluent are most practical when dealing with a large volume of water with a relatively low concentration of organic material. These treatments are engineered applications of naturally occurring processes wherein fungi and bacteria convert organic matter to simple nonpolluting byproducts. These processes require the addition of oxygen and nutrients, and usually considerable land is necessary for ponding to allow for the required reaction time. There are several methods used to oxidize the organic matter: trickling filters, activated sludge, soil irrigation, aerated lagoons, and oxidation ponds. Trickling filters and activated sludge systems are designed to concentrate the reactive organisms and reduce the costly land requirement.

Biological treatments have successfully reduced COD and phenol levels up to 99 percent in creosote waste but penta removal data is contradictory (Reference 44). The questionable issue is the rate of biodegradation of penta and therefore its response to biological treatments. Laboratory studies have shown complete biodegradation to occur but field data is not available to substantiate this (Reference 45).

Chemical Treatment

Chemical treatment (flocculation) is used to break oil-water emulsions formed during the preserving process. Flocculation, followed by gravity separation, reduces the oil content of wastewater. Lime, ferric chloride, various polyelectrolytes, and clays of several types are used by the industry for this purpose. COD reductions of 30 to 80 percent, generally as a result of oil removal, can be achieved (Reference 27).

Activated Carbon Adsorption

Though not presently practiced by the industry, the feasibility of activated carbon adsorption for reduction of phenolic compounds, including chlorophenols and high-molecular-weight organics, such as PAH's and phthalates, has been demonstrated by several investigators. Since carbon adsorption of flocculated wood preserving wastewaters results in high carbon usage rates, the concept of activated carbon as a polishing treatment for removal of phenols, PAH's and residual COD following biological treatment appears to have merit. In this configuration, biological treatment removes most of the wood sugars and other readily biodegradable organics prior to carbon adsorption, thus decreasing carbon doses required and greatly increasing carbon life (Reference 27).

Soil Irrigation

Ten plants in the wood preserving industry currently use spray or soil irrigation as a final wastewater treatment step. This technique allows for percolation and evaporation of the water coupled with biodegradation of the organic species, thus reducing COD and organic concentrations. Irrigation is a viable method treatment even though it is more land-intensive and may be more expensive than other alternatives.

Summary of Wastewater Treatment Technologies

Laboratory and field data have been presented showing that organic constituents in the wastewater are emitted to the atmosphere. In addition, it has also been shown that treatment of the wastewater, by flocculation (pH adjustment) and filtration prior to evaporation can lead to reductions in the emission rates of the toxic substances. Biodegradation, chemical flocculation, carbon adsorption and soil irrigation have also been reported to reduce the COD and organic content in the wastewater.

6.2 SOLID WASTE DISPOSAL

The amount of solid waste material generated by the wood preserving industry depends on the preservative used and the treatment technologies employed. The water effluent from waterborne salt processes are recycled to the process. Insoluble materials contained in the process water are filtered out and disposed of. However, since the preservative category does not generate a waste containing organic compounds, the treatment category will not be discussed further.

Each of the treatment processes discussed in Section 6.1 for wastewater result in the formation of a sludge material. The volume of material generated is presented in Table XXXV. This material is typically disposed of in landfills, onsite if land availability permits, or offsite. Incineration of the solid waste is not currently practiced. Work has been conducted, however, that indicates the formation of toxic dioxins during the combustion of chlorinated phenols (References 46 through 48). Additional testing of the combustion of these preservatives is to be conducted. See Section 8 for a more detailed discussion.

TABLE XXXV. SLUDGE GENERATION BY IN-PLACE WOOD PRESERVING WASTEWATER TREATMENT SYSTEMS (Reference 27)

Treatment technology	Average unit sludge generation (m^3/1,000 m^3 of production)	Range of unit sludge generation (m^3/1,000 m^3 of production)
Current pretreatment -- Gravity oil-water separation followed by chemical flocculation and slow sand filtration or equivalent	0.486	0.054 to 1.486
Current BPT -- Gravity oil-water separation followed by biological treatment (some plants also include flocculation/ filtration)	0.378	0.054 to 0.892
No-dischargers -- evaporation systems	0.432	0.027 to 1.999

6.3 AIR EMISSIONS

Emissions from the wood preserving industry include boiler exhaust and a variety of fugitive source emissions. Boiler stack emissions will be regulated under the Office of Air Quality Performance Standard's (OAQPS's) new source performance standards for nonfossil or industrial boilers. Reports of work quantifying the organic constituents in fugative air emissions from the wood preserving industry were not identified. These sources include the dense vapor plumes emitted as the pressure vessel is opened and wood charge removed, the treated wood as it cools, and the vacuum exhaust. Testing programs to quantify these emissions are to be conducted. See Section 8 for a more detailed discussion.

A control technique for emissions from the retort and treated wood consists of a water blanket around the opening. The blanket is formed using spray headers mounted a few centimeters from the open end of the retort. The sprays cover the end of the retort and the emerging wood. The wood is cooled to approximately 45°C thereby reducing the driving force for emission of high-molecular-weight compounds. The organics are transferred to the water phase which then must be treated prior to ultimate disposal.

The evaporation devices used to reduce wastewater volumes are not equipped with devices to remove organic compounds from the air emissions.

This is due to the low concentrations of organics present per volume of gas. Control of these organics, as described previously, would most likely be by flocculation and filtration or other treatment techniques for the wastewater prior to possible air emission.

Information was not identified or collected in the field that would allow quantification or estimation of the drift from either the cooling tower or a spray pond. The cooling tower tested was designed and operated such that no drift was detected during the test sequence. Drift is expected to contain organic constituents similar to the recirculating liquid. Therefore, the impact on air emissions could be estimated from the charge material composition and an assumed amount of drift. A hypothetical case is presented in Table XXXVI for a cooling tower operating under saturated conditions. Similar calculations could be developed for other evaporation devices.

TABLE XXXVI. ATMOSPHERIC EMISSIONS FROM A HYPOTHETICAL COOLING TOWER

Component	Charge (ppb)	Evaporated (ppb)	Drift (ppb)	Total Air (ppb)	Sludge
Phenol	1,000	1,000	--	1,000	N/D
2-nitrophenol	4,000	N/D	0.4	0.4	4,000
2-4-6 trichlorophenol	26,000	N/D	2.6	2.6	25,997
Penta	1,000,000	N/D	100.0	100.0	999,900

N/D -- None detected

SECTION 7

IMPACT OF EVAPORATION ON MULTIMEDIA EMISSIONS INVENTORY

The primary emphasis of the work conducted during this program has been the evaporation of wastewaters generated during wood preserving operations. In this section, the impact of evaporation technology on the inventory of industry emissions is developed from data on established industry practices and research results. To establish the mass emissions of organic material from a typical wood treating plant, the projected wastewater generation rate and constituent concentrations identified in Section 5 are coupled with the fractional emission rates determined in Section 6. Major operational factors affecting these projections are also presented. These factors include the organic emissions due to operation of thermal, atmospheric and pretreatment systems, and the projected probability of plant closure under the burden of the promulgated wastewater discharge regulations.

7.1 FRACTIONAL EMISSION RATES OF EVAPORATION DEVICES AND EMISSION PROJECTIONS

The discussion presented in Section 6 showed the effect of temperature and pH on the emission of organic constituents of various molecular weights. For solution temperatures near atmospheric temperature, such as in the case of spray ponds, cooling towers, and solar ponds, it has been shown that the low molecular weight organics, such as benzene, toluene, and phenol, may be emitted. As the molecular weight of an organic constituent increases, the probability that the constituent will remain in the sludge fraction also increases. Likewise, as the solution temperature increases, such as in pan evaporation, the probability of additional organic emissions exists. For penta solutions, it has also been shown that reductions in the organics in solution can be obtained by pH adjustment. Reducing the pH to 2 followed by filtration, results in the control of most chlorinated organic species. The sludge fraction is increased by the mass of organics removed by filtration, thus reducing organic emissions to the atmosphere. Creosote wastewaters are less affected by pH adjustment and filtration. Using these guidelines, projections of the industrywide inventory of emissions, both sludge and atmospheric, can be generated using the estimated mass of selected pollutants contained in wastewaters from Table XXV.

Assume that the data contained in Table XXV represent the mass of pollutants entering an evaporation device. Secondly, assume the data presented in Table XXXVII represent the impact of treatment and or evaporation on the constituents. The values presented in Table XXXVII are based on the

TABLE XXXVII. EFFECT OF WASTEWATER TREATMENT AND/OR EVAPORATION ON ORGANIC CONSTITUENTS

Preservative Component	Fraction of organic constituent emitted during evaporation at atmospheric temperature	Fraction of organic constituent removed during wastewater treatment (acidification and filtration)	Fraction of organic constituent emitted during evaporation at elevated (>60°C) temperature
Penta			
Benzene	100	0	100
Ethylbenzene	100	0	100
Toluene	100	0	100
Phenol	100	0	100
Penta	0	85	0
Trichlorophenol	0	85	0
Creosote			
Naphthalene	0	35	95
Fluorene	0	60	95
Phenanthrene/ anthracene	0	80	40
Pyrene	0	90	20
Fluoroanthene	0	90	20

analytical data presented in Section 6 and engineering interpretation of the data. The pollutants selected for these projections include toluene, benzene, pyrene, fluoranthene, phenanthrene/anthracene, naphthalene, fluorene, penta, phenol, and trichlorophenol. The fate of each pollutant was examined when it is evaporated under "as received" conditions. In addition, two categories of evaporation device were examined: thermal or pan evaporators operating at elevated temperature and solar, spray, and cooling tower systems operating at atmospheric temperature. Tables XXXVIII through XLIX present the projected mass emissions of organics.

Review of the data presented in Tables XXXVII through XLIX show several impacts of treatment and/or evaporation. Primarily, it is expected that all volatile organics, including phenol, will be emitted from the wastewater. Though quantitative data are not available at the time of this report, other sources, primarily vacuum vents from the retorts, may represent more significant emission sources for volatiles than does the evaporation of the wastewater.

The second impact is the increased emissions of heavier organics at elevated temperatures. Without treatment of the wastewater, significant organics could be emitted to the atmosphere. The use of wastewater treatment, whether acidification and filtration or flocculation and gravity settling, is expected to reduce the emissions of nonvolatile organics during evaporation. Clearly, evaporation of wastewaters with minimal use of thermal enhancement during poor weather operation represent the lowest source of air emissions.

Based on current disposal technology, and assuming that a majority of the industry utilizes some type of evaporation, a projection of the distribution of the pollutants can be generated. This estimate is based on the projected growth rate of the industry and, in particular, the projected change in the use of each preservative. Between the 1978 base year and the year 2000, the use of creosote is expected to decline at a rate of 1.5 percent per year for 22 years or 38.8 percent, resulting in a 38.8 percent decrease in the pollutants for disposal. Likewise, the use of penta is projected to increase at a rate of 6.8 percent per year for 22 years or 425.2 percent, resulting in a 425.2 percent increase in the pollutants for disposal. Since it is expected that the wastewater represents a negligible source of volatile organics compared to the vacuum vents and other sources, and since the nonvolatile constituents contained in penta were more readily removed by water treatment, penta may represent a decreased impact to air emissions than other preservatives when coupled with pH adjustment and filtration. Thus, a positive impact can be obtained with the use of wastewater treatment coupled with evaporation at atmospheric temperature.

7.2 REGULATORY IMPACT ON EMISSIONS BURDEN AND CONTROL COSTS

The EPA's Effluent Limitations will require further industry wastewater discharge control that will impact industry emissions. Several waste treatment processes and the EPA limitations requiring use of these processes are presented in the following paragraphs.

TABLE XXXVIII. PROJECTED FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF UNTREATED WASTEWATER, OPEN STEAMING USING PENTA (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Evaporation at atmospheric temperature		Evaporation at elevated (>60°C) temperatures	
		Air	Sludge	Air	Sludge
Benzene	836.3	836.3	ND	836.3	ND
Ethylbenzene	514.6	514.6	ND	514.6	ND
Toluene	1,001.7	1,001.7	ND	1,001.7	ND
Phenol	19,528.4	19,528.4	ND	19,528.4	ND
Penta	22,009.7	ND	22,009.7	19,808.7	2,201.0
Trichlorophenol	180.1	ND	180.1	162.1	18.0

ND -- None detectable

TABLE XXXIX. PROJECTED FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF UNTREATED WASTEWATER, CLOSED STEAMING USING PENTA (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Evaporation at atmospheric temperature		Evaporation at elevated (>60°C) temperatures	
		Air	Sludge	Air	Sludge
Benzene	212.6	212.6	ND	212.6	ND
Ethylbenzene	130.8	130.8	ND	130.8	ND
Toluene	254.7	254.7	ND	254.7	ND
Phenol	4,964.9	4,964.9	ND	4,964.9	ND
Penta	5,595.7	ND	5,595.7	5,036.1	559.6
Trichlorophenol	50.0	ND	50.0	45.0	5.0

ND -- None detectable

TABLE XL. PROJECTED FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF UNTREATED WASTEWATER, BOULTONIZING USING PENTA (UNITS -- kg/YEAR, BASE YEAR 1978)

		Emissions from untreated wastewater evaporated at atmospheric temperature		Emissions from untreated wastewater evaporated at elevated (>60°C) temperature	
Organic	Untreated wastewater	Air	Sludge	Air	Sludge
Benzene	N/A				
Ethylbenzene	N/A				
Toluene	N/A				
Phenol	19.2	19.2	ND	19.2	ND
Penta	2,949.9	ND	2,949.9	2,654.9	295.0
Trichlorophenol	N/A				

ND -- None detectable

TABLE XLI. PROJECTED FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF TREATED WASTEWATER, OPEN STEAMING USING PENTA (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Mass of organic removed during wastewater treatment	Emissions from treated wastewater evaporated at atmospheric temperature		Emissions from treated wastewater evaporated at elevated (>60°F) temperature	
			Air	Sludge	Air	Sludge
Benzene	836.3	ND	836.3	ND	836.3	ND
Ethylbenzene	514.6	ND	514.6	ND	514.6	ND
Toluene	1,001.7	ND	1,001.7	ND	1,001.7	ND
Phenol	19,528.4	ND	19,528.5	ND	19,528.4	ND
Penta	22,009.7	18,708.2	ND	3,301.5	2,971.4	330.1
Trichlorophenol	180.1	153.1	ND	27.0	24.3	2.7

ND -- None detectable

TABLE XLII. FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF TREATED WASTEWATER, CLOSED STEAMING USING PENTA (UNITS -- kg/YEAR, BASE YEAR 1978)

			Emissions from treated wastewater evaporated at atmospheric temperature		Emissions from treated wastewater evaporated at elevated (> 60^{o}C) temperature	
Organic	Untreated wastewater	Mass of organics removed during wastewater treatment	Air	Sludge	Air	Sludge
Benzene	212.6	ND	212.6	ND	212.6	ND
Ethylbenzene	130.8	ND	130.8	ND	130.8	ND
Toluene	254.7	ND	254.7	ND	254.7	ND
Phenol	4,964.9	ND	4,964.9	ND	4,964.9	ND
Penta	5,595.7	4,756.3	ND	839.4	755.3	83.9
Trichlorophenol	50.0	42.5	ND	42.5	38.3	4.2

ND -- None detectable

TABLE XLIII. FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF TREATED WASTEWATER, BOULTONIZING USING PENTA (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Mass or organic removed during wastewater treatment	Emissions from treated wastewater evaporated at atmospheric temperature		Emissions from treated wastewater evaporated at elevated (>60°C) temperature	
			Air	Sludge	Air	Sludge
Benzene	N/A					
Ethylbenzene	N/A					
Toluene	N/A					
Phenol	19.2	19.2	19.2	ND	19.2	ND
Penta	2,949.9	2,507.4	ND	442.5	398.3	44.2
Trichlorophenol	N/A					

ND -- None detectable

TABLE XLIV. PROJECTED FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF UNTREATED WASTEWATER, OPEN STEAMING USING CREOSOTE (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Emissions from untreated wastewater evaporated at atmospheric temperature		Emissions from untreated wastewater evaporated at elevated (>60°C) temperature	
		Air	Sludge	Air	Sludge
Naphthalene	11,213.0	ND	11,213.0	10,652.4	560.6
Fluorene	3,257.1	ND	3,257.1	3,094.2	162.9
Phenanthrene/ anthracene	10,892.6	ND	10,892.6	4,357.0	6,535.6
Pyrene	3,203.7	ND	3,203.7	640.7	2,563.0
Fluoranthene	4,378.4	ND	4,378.4	875.7	3,502.7

ND -- None detectable

TABLE XLV. PROJECTED FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF UNTREATED WASTEWATER, CLOSED STEAMING USING CREOSOTE (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Emissions from untreated wastewater evaporated at atmospheric temperature		Emissions from untreated wastewater evaporated at elevated (>60°C) temperature	
		Air	Sludge	Air	Sludge
Naphthalene	2,850.8	ND	2,850.8	2,708.3	142.5
Fluorene	828.1	ND	828.1	786.7	41.4
Phenanthrene/ anthracene	2,769.3	ND	2,769.3	1,107.7	1,661.6
Pyrene	814.5	ND	814.5	162.9	651.6
Fluoranthene	1,113.2	ND	1,113.2	222.6	890.6

ND -- None detectable

TABLE XLVI. PROJECTED FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF UNTREATED WASTEWATER, BOULTONIZING USING CREOSOTE (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Emissions from untreated wastewater evaporated at atmospheric temperature		Emissions from untreated wastewater evaporated at elevated (>60°C) temperature	
		Air	Sludge	Air	Sludge
Naphthalene	1,975.0	ND	1,975.0	1,876.3	98.7
Fluorene	518.3	ND	518.3	492.4	25.9
Phenanthrene/ anthracene	767.3	ND	767.3	306.9	460.4
Pyrene	122.0	ND	122.0	24.4	97.6
Fluoranthene	177.4	ND	177.4	35.5	141.9

ND -- None detectable

TABLE XLVII. FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF TREATED WASTEWATER, OPEN STEAMING USING CREOSOTE (UNITS -- kg/YEAR, BASE YEAR 1978)

			Emissions from treated wastewater evaporated at atmospheric temperature		Emissions from treated wastewater evaporated at elevated (>60°C) temperature	
Organic	Untreated wastewater	Mass of organic removed during wastewater treatment	Air	Sludge	Air	Sludge
Naphthalene	11,213.0	3,924.6	ND	7,288.5	6,924.0	364.4
Fluorene	3,257.1	1,954.3	ND	1,302.8	1,237.7	65.1
Phenanthrene/ anthracene	10,892.6	8,714.1	ND	2,178.5	871.4	1,307.1
Pyrene	3,203.7	2,883.3	ND	320.4	64.1	256.3
Fluoranthene	4,378.4	3,940.6	ND	437.8	87.6	350.2

ND -- None detectable

TABLE XLVIII. FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF TREATED WASTEWATER, CLOSED STEAMING USING CREOSOTE (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Mass of organic removed during wastewater treatment	Emissions from treated wastewater evaporated at atmospheric temperature		Emissions from treated wastewater evaporated at elevated (>60°C) temperature	
			Air	Sludge	Air	Sludge
Naphthalene	2,850.8	997.8	ND	1,853.0	1,760.4	92.6
Fluorene	828.1	496.9	ND	331.2	314.6	16.6
Phenanthrene/ anthracene	2,769.3	2,215.4	ND	553.9	221.5	332.4
Pyrene	814.5	733.1	ND	81.4	16.3	65.1
Fluoranthene	1,113.2	1,001.9	ND	111.3	22.3	89.0

ND -- None detectable

TABLE XLIX. FATE OF ORGANIC CONSTITUENTS FROM THE EVAPORATION OF TREATED WASTEWATER, BOULTONIZING USING CREOSOTE (UNITS -- kg/YEAR, BASE YEAR 1978)

Organic	Untreated wastewater	Mass of organic removed during wastewater treatment	Emissions from treated wastewater evaporated at atmospheric temperature		Emissions from treated wastewater evaporated at elevated (>60°C) temperature	
			Air	Sludge	Air	Sludge
Naphthalene	1,975.0	691.3	ND	1,283.7	1,219.5	64.2
Fluorene	518.3	311.0	ND	207.3	196.9	10.4
Phenanthrene/ anthracene	767.3	613.8	ND	153.5	30.7	122.8
Pyrene	122.0	109.8	ND	12.2	2.4	9.8
Fluoranthene	177.4	159.7	ND	17.7	3.5	14.2

ND -- None detectable

Capital and operating cost data are presented for three evaporation systems: pan evaporators, cooling towers, and spray ponds. These do not represent costs for overall water treatment systems, but are representative of the costs of retrofitting plants to include evaporation devices. Pretreatment of process wastewater is usually required before disposal into these systems. Often gravity oil and water removal, flocculation, filtration, aerated lagoons, spray cooling ponds, and holding ponds may also be connected in series or parallel with each other.

Tables L and LI show approximate capital and total annual costs, respectively, for the three evaporation systems discussed. Table LII lists anticipated total annual costs for energy prices at twice those shown for the base period shown in Table LII (Reference 49). Cooling towers are seen to have the highest capital expenditure and also the highest total annual costs. The latter is due to the high amortization rate of the initial capital investment.

Forced evaporation systems are the second most costly. These systems will become more expensive to operate as energy costs increase. It should be noted that pan evaporation may represent the least economic impact of any of the three technologies, but also represents the greatest emitter of organic pollutants to the atmosphere.

New Sources

Cost of compliance for new sources that include the Boulton drying and steam conditioning methods have been investigated and reported by EPA (References 27 and 50). EPA did not consider inorganic processes since they do not generate a continuous wastewater stream containing organic constituents. To develop costs, process model systems were selected from Boulton and steaming processes. The treatment technology selected for the Boulton drying process waste consists of:

- Primary gravity oil-water separation
- Flocculation followed by slow sand filtration
- Evaporation in a cooling tower with provisions for additional heat input through a heat exchanger

Table LIII lists design parameters for the four model plants used for cost of compliance for new sources. Tables LIV through LVIII list costs of compliance for these outlined model plants. The total investment costs reported partially reflect the daily design production volume.

Regulatory Impact on Existing Sources

An interagency analysis of EPA's proposed effluent limitations shows that the projected costs of compliance to best available technology regulations falls disproportionately on the smaller plants (i.e., those with a lower sales volume are impacted more heavily). Twelve plants with sales under $3.5 million per year would be unlikely to be able to afford the control

TABLE L. CAPITAL COSTS OF EVAPORATION SYSTEMS (Reference 49)[a]

Pan evaporator, 200 ft^2	$ 26,000
Cooling tower, 650 gpm	$160,000
Storage tank, 600,000 gal	65,000
Flocculation-filtration	25,000
Total	$250,000
Spray pond (140 x 100 ft x 6 ft) 630,000 gal	
Land	$ 5,000
Materials	5,000
Labor	10,000
Pumps	3,000
Piping	2,000
Miscellaneous Electrical	2,500
Engineering	3,000
	$ 30,500
Flocculation-Filtration	25,000
Total	$ 55,000

[a] Cost based on June 1977 dollars

TABLE LI. TOTAL ANNUAL COSTS OF EVAPORATION SYSTEMS (Reference 49)

Evaporation System	Interest and Payments	Depreciation (15 year)	Energy	Maintenance	System Total
Pan evaporation	$ 3,418	$ 1,800	$ 9,200 to 38,000	$1,000	$15,400 to 45,200
Cooling tower	32,868	16,700	10,000	7,500	67,100
Spray pond	7,227	3,700	5,000	1,700	17,700

TABLE LII. OPERATION COSTS OF EVAPORATION SYSTEMS AT THE BASE ENERGY COSTS (REFERENCE 49)

Evaporation System	Interest and Payments	Depreciation (15 year)	Energy	Maintenance	System Total
Pan evaporation	$ 3,400	$ 1,800	$18,400 to 76,000	$1,000	$24,600 to 82,200
Cooling tower	32,900	16,700	20,000	7,500	77,100
Spray pond	7,300	3,700	10,000	1,700	22,700

TABLE LIII. MODEL PLANTS FOR NEW SOURCE PERFORMANCE STANDARDS (Reference 27)

Plant type	Design production		Wastewater flow (gal/day)
	Cubic feet/ day	Product type	
Boulton Process			
Plant A	3,200	Douglas fir poles	4,000
Plant B	8,000	Douglas fir poles	10,000
Organic steaming plants			
Plant C	6,000	Southern pine poles	3,250
Plant D	15,000	Southern pine poles	8,500

TABLE LIV. WOOD PRESERVING-BOULTON SUBCATEGORY COST SUMMARY FOR MODEL PLANT A (Reference 27)[a]

	Capital cost	Annual operating cost	Annual energy cost
Primary oil separation	$ 40,000	$ 2,500	$1,500
Flocculation and slow sand filtration	16,000	3,900	400
Pump station	6,300	1,470	1,160
Cooling tower evaporation (including recirculation pumps)	57,000	6,880	5,100
Engineering	17,900	--	--
Land	5,000	--	--
Contingency	21,330	--	--
Sludge disposal	--	1,000	--
Capital recovery	--	18,620	--
Insurance and taxes	--	3,730	--
Labor	--	20,000	--
Total	$163,530	$58,100	$8,160

[a]Cost base year June 1977.

TABLE LV. WOOD PRESERVING-BOULTON SUBCATEGORY COST SUMMARY FOR MODEL PLANT B (Reference 27)[a]

	Capital cost	Annual operating cost	Annual energy cost
Primary oil separation	$ 56,750	$ 3,000	$1,750
Flocculation and slow sand filtration	19,500	5,200	400
Pump station	7,300	1,900	1,480
Cooling tower evaporation (including recirculation pumps)	82,000	14,990	12,500
Engineering	24,830	--	--
Land	7,500	--	--
Contingency	29,680	--	--
Sludge disposal	--	2,000	--
Capital recovery	--	25,850	--
Insurance and taxes	--	5,190	--
Labor	--	25,000	--
Total	$227,560	$83,130	$16,130

[a] Cost base year June 1977

TABLE LVI. WOOD PRESERVING-STEAMING SUBCATEGORY COST SUMMARY FOR MODEL PLANT C (Reference 27)[a]

	Capital cost	Annual operating cost	Annual energy cost
Primary oil separation	$ 40,000	$ 2,500	$1,500
Flocculation and slow sand filtration	16,000	3,900	400
Pump station	5,790	1,290	1,020
Spray evaporation	92,000	1,590	270
Engineering	23,070	--	--
Land	9,000	--	--
Contingency	27,880	--	--
Sludge disposal	--	1,000	--
Capital recovery	--	24,050	--
Insurance and taxes	--	4,880	--
Labor	--	20,000	--
Total	$213,700	$59,200	$3,200

[a] Cost base year June 1977

TABLE LVII. WOOD PRESERVING-STEAMING SUBCATEGORY COST SUMMARY FOR MODEL PLANT D (Reference 27)[a]

	Capital cost	Annual operating cost	Annual energy cost
Primary oil separation	$ 56,750	$ 3,000	$1,750
Flocculation and slow sand filtration	19,500	5,200	400
Pump station	6,800	1,710	1,340
Spray evaporation	155,000	1,620	280
Engineering	35,710	--	--
Land	19,500	--	--
Contingency	43,990	--	--
Sludge disposal	--	2,000	--
Capital recovery	--	37,320	--
Insurance and taxes	--	7,730	--
Labor	--	25,000	--
Total	$337,250	$83,580	$3,770

[a]Cost base year June 1977

TABLE LVIII. POTENTIAL PLANT CLOSURES UNDER BAT ALTERNATIVES (Reference 50)

		Probability of closure	
		zero discharge	
Plant type/sales	Total plants	High	Moderate
Organic-steaming-indirect			
$ 700	4	1	2
1,800	4	2	1
3,500	11	5	2
7,500	10	--	--
Not applicable	2	--	--
Total	31	8	6
Organic-steaming-direct			
$ 700	5	2	2
All others	5	--	--
Total	10	2	2
Organic-Boulton			
$ 200	1	1	--
700	1	--	1
1,800	1	--	--
3,500	2	--	1
7,500	6	--	--
Total	11	1	1

evaluation is based on a plant likely to incur operating losses as a result of compliance costs or being unable to finance the investment for the necessary control equipment.

Table LIV lists probabilities for plant closure due to costs to attain zero water discharge. Eleven plants are likely to shut down and 10 others face potential shutdown if zero discharge regulations are implemented. Though the closure of any plant would be significant to individuals directly impacted, it is expected that the lost treating capacity could be replaced by excess capacity at other facilities. In addition, potential plant closures are not expected to initiate additional research efforts to identify new treatment processes or preservatives.

SECTION 8

REVIEW OF ONGOING WOOD TREATING PRESERVING AND WASTE DISPOSAL STUDIES

The EPA, Department of Agriculture (USDA) and National Institute for Occupational Safety and Health (NIOSH) are presently studying the effects of the disposal of wood treating wastes on the environment, the impact of the use of treated products, and other questions relating to the use of creosote, penta, and other preservatives. Presented in this section is a review of the objective, scope, general approach, and status to date of ongoing studies relevant to this work. This information, coupled with the technical discussions presented earlier in this report, provides a sound basis for an objective assessment of the need for future study.

1. Characterization of Multimedia Emissions from a Wood Treating Plant

Project Officer: Don Wilson
EPA/IERL, Food and Wood Products Branch
Cincinnati, Ohio 45268
(513) 684-4227

Contractor Program Manager: Richard S. Merrill
Acurex Corporation
Mountain View, California 94042
(415) 964-3200

Contract Number: 68-03-2567 (Task 28)
Term: June to March 1981

As a means of continuing and expanding the work initiated under Contract 68-03-2584 (the work reported by this document), Acurex has been contracted to perform additional sampling and analysis activities at selected wood treating facilities. The sampling and analysis will include each of the following sources for volatile and nonvolatile organic species:

- Thermal evaporation system
    - Liquid feed stream
    - Air emissions
    - Sludge

- Treatment cylinder(s)
    - Fugitive emissions
- Spray pond evaporation device
    - Liquid feed stream
    - Air emissions
    - Sludge
- Destruction efficiency during incineration of penta and creosote sludge materials

The analysis will include screening by the Acurex Environmental Laboratory for dioxins and furans.

Testing of the thermal evaporation device will include 3 consecutive days of testing at the system operating conditions. Information, including liquid temperatures, solution pH values, stagnant layer depth, as well as the data necessary to determine the mass emissions of organics, will be collected.

Fugitive emissions will be collected from one or more retorts, one creosote, and one penta treatment cycle as available. The data collected will yield qualitative information describing organic emissions from the pressure vessels. If two retorts are not available for testing, sampling of emissions from the cooling wood, open process vessels, or other source of fugitive emissions will be tested.

An additional task will be the sampling and analysis of a spray pond evaporation system. Again, the sampling will be for any organic emissions. Special sample collection hardware will be used for this test sequence. The hardware is designed to measure organic concentration gradients above the surface of the liquid.

The final part of this contract will be to characterize the destruction efficiency of a stoker-type incinerator when burning wood wastes mixed with a creosote and penta sludge from an evaporation system. Samples will include the boiler fuel (wood and sludge), bottom ash, particulate control device ash, and gaseous and particulate matter entrained in the combustion gases. Analyses will include unburned hydrocarbons, chlorinated organics, and dioxins and furans.

The program is designed to qualitatively and, wherever possible, quantitatively measure the gaseous emissions from the processing and disposal of wood treating preservative wastes. Information describing the content of sludge materials will also be collected.

2. Development of Effluent Guidelines Limitations

Project Officer: Richard Williams
EPA/Office of Water and Waste Management/Effluent Guidelines Division
Washington, D.C. 20460
(202) 426-2555

Contractor Project Director: Bevin Beaudet
Environmental Science and Engineering, Inc.
Gainesville, Florida 32602
(904) 372-3318

Contract Number: 68-01-7583
Term: February 1979 to May 1981

Effluent guidelines limitations and standards for direct and indirect dischargers and new sources were promulgated for wood preserving plants during the period 1974 through 1976. The Flannery Settlement Agreement of June 1976 and the subsequent 1977 amendments to the Clean Water Act required EPA to review its current regulations and promulgate new ones, if necessary, to control the discharge of toxic pollutants. In late 1976, EGD and its contractor initiated a thorough restudy of the wood preserving industry to update information in its data base on industry profile, subcategorization, and manufacturing processes, as well as to evaluate candidate treatment systems for removal of toxic pollutants. As a result of this study, EPA proposed, on October 31, 1979, effluent guidelines limitations and standards for the timber products point source category.

Current work in the wood preserving industry includes evaluation of public comments to the proposed regulations and the preparation of final regulations due to be completed in late 1980. Most public comment concerns pretreatment standards requiring no discharge of penta for steam and Boulton subcategory plants. Major issues are the potential adverse economic impact of industry regulation, the potential for adverse impact on air resources due to application of evaporation technology, and the ultimate fate of penta in POTW's.

EGD and its contractor are also conducting an evaluation of best management practices for the wood preserving industry. The purpose of this study is to identify practices in the manufacturing of preserved wood products that will minimize the amount of toxic pollutants released to the environment through stormwater runoff from process areas and storage yards, and through the handling and disposal of sludge and other solid wastes. Included in this study is a review of candidate innovate treatment technologies and a study to quantify the amount and characteristics of sludge and solid wastes generated by wood preserving plants.

3. Hazardous Chemicals in the Wood Preserving Industry

Project Officers: Paul Cammer -- penta and creosote
Stephanie Roan -- Arsenicals
EPA/Office of Pesticides and Toxic Chemicals
Washington, D.C. 20460
(202) 557-7451

Term: 1978 (Ongoing)

This is an ongoing program in support of the RPAR published in the Federal Register in August 1978. The notice of registration of hazardous chemicals used in the wood preserving industry was Position Document 1 (PD1) from the Office of Pesticides and Toxic Substances and elicited testimonials and other rebuttal arguments from industry spokesmen.

An in-house analysis of these rebuttals has been completed by the Special Pesticides Branch and they are presently assembling a risk/benefit analysis based on the rebuttal evidence. Publication of the analysis is expected by June 1981 and will appear in the Federal Register as PD2-3.

Following time allowed for additional comment by the wood preserving industry, a final document, PD4, will be published and will represent the final position addressing the manufacturing technology of making wood products impregnated with arsenicals, penta, or creosote.

There is no time schedule established for this final step.

4. Pentachlorophenol

Project Officer: Michael W. Slimak
EPA/Office of Water Quality
Washington, D.C. 20460
(202) 426-2503

Contractor: Arthur D. Little
Cambridge, Massachussetts 02140
(617) 864-5770

Contract Numbers: 68-01-3857 (penta) and 68-01-5949 (creosote)
Term: November 1979 to June 1981

The study describes penta and its uses in all industries, with the wood preserving industry being of primary interest. The scope of the project will be an examination of the chemicals in:

- Manufacturing processes where it is used and any associated effluents
- Preserved wood and any soil or water leachates associated with the use of the wood

There are two purposes for this study:

- To determine the need for controls and/or regulations pertaining to the use of penta in a manufacturing process
- To enable the water quality division to make recommendations for further study if it is deemed necessary and more appropriately carried out by other government agencies

5. Characterization of Wood Preservatives and the Wood Treating Industry

Project Coordinator: Lee Gjovik
USDA, Forest Service
U.S. Forest Products Laboratory
Madison, Wisconsin 53705
(608) 264-5600 Ext. 5819

Project Officer: Dr. Warren Thompson
Project Directors: Drs. Gary M. McInnis and Leonard Ingram
Associated Laboratory
Mississippi Forest Products Utilization Laboratory
Mississippi State University, Mississippi 39762
(601) 325-2116

Term: Ongoing to September 1981

There are two separate programs to characterize the wood preserving industry and chemicals used in wood treatment processes being directed by the USDA Forest Service in their Forest Products Laboratory.

Project 1 is an assessment of creosote, penta, arsenical salts, and their uses. The study is being handled by the U.S. Forest Service staff from their laboratory in Madison, Wisconsin.

The final report of the assessment is due in April 1981 to be published in two volumes: Volume 1 dealing with wood preservative uses, and Volume 2 with nonwood preservative uses.

Included in this study is a discussion of the:

- Chemicals and their fate in the environment
- Technology used to treat wood with these chemicals
- Waste effluents from the treatment processes
- Control of the effluents

Project 2 is a laboratory study conducted by the Mississippi Forest Products Utilization Laboratory followed by field tests conducted by the USDA Forest Service Laboratory staff from Madison, Wisconsin. This program has been divided into seven tasks. Tasks 1, 2, and 3 deal with penta; Tasks 4, 5, and 6 with creosote; and Task 7 with both penta and creosote.

- Task 1 (Agreement USFS 12-88) is a study of the vaporization rate of penta into air

- Task 2 (Agreement USFS 12-143) is a study of the effect of solvents on the evaporation rate

- Task 3 (Agreement FP 80-0236) studies the effect of film-forming coatings such as paints, varnishes, and polyurethane on the vaporization rate
- Task 4 (Agreement USFS 12-156) is a study of the migration of creosote from marine pilings into saltwater

- Task 5 (Agreement FP 80-0189), similar to Task 2, is a study of the effect of coatings on vaporization rates of creosote

- Task 6 (Agreement USFS 12-186) is a study of the migration rates of creosote into the air

- Task 7 (Agreement FP 80-0190) is an identification of the breakdown products of creosote and penta under both chemical and physical conditions

Tasks 1 and 2 have been completed and have had field studies conducted to verify the laboratory results. These reports will be published in late 1980. Task 3 is to be completed in its laboratory investigation soon but has not been field tested. There has been one progress report published on Task 4, but no final time schedule is available on Tasks 4 through 7.

6. Physical Migration of Creosote and Pentachlorophenol Out of Treated Wood

Project Officer: Jay Gile
EPA/Environmental Research Laboratory
Corvallis, Oregon 97330
(503) 757-4601

Term: March 1979 to December 1980

Concerns expressed by the wood preserving industry in response to the RPAR prompted the Office of Pesticide Programs to request this study which began in the spring of 1979.

The main emphasis of the study is to derive quantitative information on the physical movement of creosote, penta, and tributyl-tin-oxide from treated wood through soil, plant, and invertebrate material. These investigations are being carried out using radiolabeled materials introduced into a simulated ecosystem in the laboratory. Tributyl-tin-oxide is being studied in the same system because it has been proposed as a possible chemical alternative to creosote and for use as a wood preservative.

The abstracts of the International Tin Research Institute indicate that tributyl-tin-oxide and other organo-tin compounds are used in Europe as wood preservative chemicals. The report on this work at the Environmental Research

Laboratory has been submitted to the Office of Pesticide Programs, and publication is expected by March 1981.

7. Standards Development for Solid Waste

Project Officer -- Katherine Jenkins
EPA/Office of Solid Waste
Washington, D.C. 20460
(202) 755-9187

The development of standards and operating procedures for generators and handlers of solid waste affects the wood preserving industry, since their effluent is deemed toxic under RCRA. Permit standards and other regulations from the Office of Solid Waste are for classes of toxic wastes and there are no plans to make regulations industry specific.

8. Incineration of Hazardous Waste

Project Officer: Richard Carnes
EPA/Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268
(513) 684-4417

Contractor Project Officer: Frank Whitmore
Versar, Inc.
Springfield, Virginia 22151
(703) 750-3000

Contract Number: 68-03-2627
Term: 1978 to 1981

The purpose of this project is to investigate the thermal destruction of hazardous waste generated by manufacturing processes. Combustion will be in a rotary kiln with an afterburner to be built in Pine Bluffs, Arkansas. The present schedule calls for the incinerator to be operational by early 1981, and with time allowed for breaking in and testing the equipment, the first waste stream should be scheduled for incineration by August 1981.

The initial burn will include still bottoms and other penta waste streams from wood preserving operations. Attention will be given to the presence or absence of dioxins, furans, and any other combination products that might be transferred from the kiln to the afterburner.

Waste products from operations where creosote is used to treat wood are scheduled to be tested in this system at a later date. There are presently no plans to incinerate the wood products that have been treated with either penta or creosote.

9. Assessment of the Workplace Environment

Project Officer -- James Oser
NIOSH/Industrial Hygiene Branch
Cincinnati, Ohio 45226
(513) 684-2876

Contract Project Director: Allan Todd
Stuart Todd Associates
Wayne, Pennsylvania 19087
(215) 687-2030

Contract Number: 210-78-0060
Term: Spring 1979 to Spring 1981

The industrial hygiene study of the wood preserving industry is to provide a characterization of the workplace environment for both the employee and employer. Air samples have been taken from 10 different plants and will be analyzed to provide data on fugitive emissions in the following five areas:

- Opening treatment tank doors
- Open treatment tanks
- Mixing and/or formulation of the chemicals onsite
- Addition of the chemicals to the tanks
- Vapors coming off the wood after removal from the treatment tanks

The laboratory analysis of these samples has been completed and a final report is due in 1981. This report will also include a study of effects of the wood preserving chemicals on skin contact.

The Industrial Hygiene Branch is considering two future studies pertaining to wood preservative chemicals and treatment processes:

- A medical effects characterization that would include both mortality and epidemiology studies

- A study of the best available in-process control technology for pesticide emissions

10. Criteria Document on Creosote and Penta

Project Officer -- James McCracken
NIOSH/Division of Criteria Documentation and Development
Rockville, Maryland 20857
(202) 443-2140

This study would also concentrate on creosote and penta in the workplace and the effects on employer and employees. Plans for this work are being held in suspension pending the results of the other studies being carried out by NIOSH and EPA.

11. Incineration of Penta Treated Boxes

Project Officer: W. Timothy Oppelt
EPA/IERL/Incineration Branch
Cincinnati, Ohio 45268
(513) 684-4417

Contractor: Department of Defense Disposal Unit
Battlecreek, Michigan

For this project the Department of Defense is seeking to use the DOE two-stage incinerator at the Los Alamos National Scientific Laboratory.

The project is being delayed on procedural grounds, but is expected to be completed by July 1981.

12. Contaminated Waste

Project Officer: E. Timothy Oppelt
EPA/Industrial Environmental Research Laboratory, Incineration Branch
Cincinnati, Ohio 45268
(513) 584-4417

Contractor Project Officers: Lts. Templin and Bartell
Department of the Army
Hygiene Office

This interagency project will be a short-term trial test burn of penta-treated boxes using the Army's contaminated waste processor. The facility is a single chamber overfire air incinerator located at Tooele, Utah.

Although planned for 1 year ago, this project has been delayed because of complications arising from the possibility that there is residual explosive remaining in the boxes.

13. Health and Environmental Effects of Selected Toxic Water Pollutants

Project Officer: John J. Carroll
EPA/Water Regulations and Standards, Criteria Branch
Washington, D.C. 20460
(202) 245-3042

Contractor Project Director: Dr. Sam Petrocelli
EG&G Bionomics
Wareham, Massachusetts 02571
(617) 295-2550

Contract Number: 68-01-4646
Term: January 1977 to December 1979

This project has studied the toxic effects of 100 water pollutants. Included in this study were naphthalene, nitrobenzene, 4-nitrophenol, and

2,4-nitrophenol; all of which are found as breakdown products from wood treating chemicals. The tests included fresh water and marine acute and embryo-larval studies, bioconcentration studies, Ames tests, and determination of octanol partition coefficients.

The data from these experiments is available on request although is has not been published. Complete publication as a series of journal articles is expected within 1 year.

14. Removal of Priority Pollutants by Filter Aid/Powdered Activated Carbon

Project Officer: Brian Westfall
EPA/IERL
Cincinnati, Ohio 45268
(513) 684-4227

Contractor Project Director: Alan Wirsig
Johns-Manville Corporation
Denver, Colorado 80217
(303) 978-5566
Contract Number 68-03-2806

This work concerns the investigation of the effect of the addition of activated carbon to a diatomaceous earth filter for use in removing priority pollutants from a waste stream. Penta, polychlorinated biphenyls, and hydroacetic acid have been studied with this technique.

The work regarding penta in wood preserving wastes has been completed and progress reports are available on request. The final report covering all these chemicals is to be published by July 1981.

15. Waste-Recycle Systems

Project Officer: Don Wilson
EPA/IERL
Cincinnati, Ohio 45268
(513) 684-4227

Contractor Project Director: A. Shum
Pacific Wood Treating Company
Richfield, Washington 98642
(206) 887-3562

Contract Number: S-805179
Term: 1978 to May 1981

This demonstration project has studied the effectiveness of ultrafiltration and reverse osmosis as a method of purifying mixed organic and inorganic wastes. The wastes studied have included varying concentrations of creosote, penta, and arsenical salts. A draft report is due by February 1981, with the final published by June 1981.

16. Phenolic Compounds

Project Officers: Don Wilson and Brian Westfall
EPA/IERL
Cincinnati, Ohio 45268
(513) 684-4227

Contractor Project Director: Willard Warren
Edward C. Jordan Company
Portland, Maine 04112
(207) 775-5401

Contract Number: 68-03-2605
Term: November 1978 to May 1981

The final report of this study entitled "The Removal of Phenolic Compounds From Wood Preserving Wastewater," has been submitted and publication is expected in May 1981. The work included bench-scale and pilot-scale studies at two wood preserving facilities.

Conclusions

To determine if additional study is required to characterize the multimedia emissions from the wood treating industry, Table LIX has been prepared. This table presents a summary of work that has been or is being performed. Information was obtained from the literature and from project officers conducting the work. In addition, if work is being conducted, it must be qualitative or quantitative for the organic constituents in the waste stream to be included. Recommendations are presented in Section 3.0.

It can be seen from this table that the primary emission sources, with the exception of spray ponds, will have been qualitatively or quantitatively evaluated for organics at the completion of all ongoing programs. Those sources still requiring study include the nonprocess wastewater sources, such as runoff, cooling waters, and fugitive air emissions from sources such as hoods, vents, and gas purging streams.

This table is presented to indicate where studies have been or are being conducted. It should not be interpreted that the data are necessarily credible or universally applicable to the information requirements of all agencies. Therefore, it is recommended that the content of past and present studies be examined carefully before acceptance of the work or establishment of new programs.

TABLE LIX. STUDY AREAS DEFINING THE MULTIMEDIA EMISSIONS FROM THE WOOD TREATING AND WOOD TREATING PRODUCTS INDUSTRY

	Process wastewater								Wastewater treatment							Evaporative air emissions				Fugitive air emissions							Sludge disposal			Preserv-ative			Product-environmental impact			
Agency	Plant runoff -- storm water	Plant runoff -- housekeeping	Oil-water separator	Wood cooling water	Contained spillage	Regulations	Regulatory impact	RPAR	pH adjustment	Biological oxidation	Chemical oxidation	Coagulation	Extraction	Adsorption	Evaporation	Still ponds	Pan evaporators	Spray ponds	Cooling towers	Chemical storage	Chemical transport	Open treatment vessels	Opening pressurized retorts	Gas purging of retorts	Vacuum exhaust gas	Hoods and vents	Evaporator sludge analysis	Landfill leachability	Incineration	Health effects	Exposure -- in-plant	Preservative usage and fate	Chemical migration to soil/water	Chemical vaporization to air	Degradation products	Incineration of treated wood
EPA																																				
EGD	X					X	X																				X									
OWQPS						X																														
OSW						X																					X					X				
OPTS								X																								X				
IERL-FWPB	X		X	X					X	X	X	X	X	X	X	X	X		X				X				X	X	X				X			
MERL																													X							
IERL-IRB																																				X
WRS																														X					X	
NIOSH																																				
I. Hygn																				X	X	X	X							X	X					
CDD																														X	X	X				
USDA																																	X	X	X	

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APPENDIX A

THERMAL (PAN) EVAPORATOR TEST PROGRAM

A wastewater evaporation test was planned and carried out for wood preserving effluents containing penta and creosote. During this program, evaluation of multimedia sampling and analysis for low-concentration select toxic organic species was carried out. Actual test results, literature reviews, and methods assessment are described.

A.1 LITERATURE REVIEW

Only limited investigations of organic chemicals in wood preserving effluents have been conducted. However, the major wood preservatives, penta and creosote, are expected to contribute the major toxic pollutants in this industry. Since chlorophenols and PAH's are the primary waterborne toxicants from the major preserving processes, a literature survey was conducted to identify sampling and analysis methodologies with particular reference to these compounds.

A.1.1 Air Sampling Methods

The analysis of air emission samples for low-level organic compounds requires a sampling system with the following characteristics:

- Efficient collection of the organic species of interest
- Equipment that is portable and can achieve reasonable air flowrates to allow for the collection of adequate sample
- Organics that are readily and quantitatively recoverable from the trapping medium

The earliest reported air sampling systems were based on bubbling the air through a trap containing an appropriate solution or solvent. For example, a text on the analysis of gaseous pollutants (Reference 51) recommends analyzing airborne phenol after trapping in a concentrated sodium hydroxide solution. Recoveries using this method were poor for a sample size below 10 mg. In addition, these impinger trains are not reliable for fairly volatile compounds.

A more recent development, arising from the need to analyze organic species during stack sampling, involves the adsorption of the organics onto high surface area polymeric adsorbents. Among the solid adsorbents used in various applications are Florisil, XAD resins, Tenax GC, and polyurethane foam plugs (References 52 through 56). Organic species tested for recovery in such systems include PAH's (Reference 53), polychlorinated biphenyls (PCB's) (Reference 55), organophosphorus pesticides (Reference 49), and many other organic species (References 53, 54, and 56).

Studies have been conducted to compare the efficiencies of different trapping media for PCB's and other gaseous pollutants (References 55 and 57). In terms of trapping efficiency and recoverability, the different adsorbents are similar; however, XAD-2 has become the sorbent of choice due to cost, achievable flowrates, and a low background contamination level (References 53 and 57). XAD-2 has specifically been shown to be an efficient sampling adsorbent for phenols and chlorophenols.

A Battelle research group has investigated the recovery of p-cresol from spiked XAD-2 cartridges in a stack gas sampling train (Reference 53). Recoveries of a 50- g loading of greater than 79 percent were obtained when the temperature was maintained at 25°C and the relative humidity at 50 percent.

A.1.2 Phenol Extraction Techniques

Acidic substances are best removed from an aqueous sample by one of two methods: acidification followed by solvent extraction or ion exchange column chromatography. Two representative literature reports on the application of ion exchange to analysis of phenols from water samples are those of Renberg (Reference 59) and Chriswell, et al. (Reference 60).

Renberg used Sephadex QAE, A-25 anion exchanger to remove phenols and other acids from a basified water sample. After acidification, the acids were eluted with benzene or methanol and derivatives prepared with diazomethane. Analysis by gas chromatography using an OV-17 column along with electron capture detection yielded recoveries of several chlorophenols to be greater than 97 percent from samples spiked at approximately 1 ppb.

Chriswell employed a similar method to analyze chloro- and alkylphenols from water samples. They used Amberlite A-26 resin and, after acidification, eluted the acids with aqueous acetone. After a subsequent partition into methylene chloride and further concentration, the phenols were analyzed using either OV-17 or Tenax-GC along with flame ionization detection. Recoveries of chloro- and alkylphenols were greater than 80 percent for concentrations as low as 15 g per liter. This method has previously proved reliable for the analysis of wood preservative waste (Reference 58).

EPA has established a protocol for the sampling and analysis of priority pollutants in industrial effluents (Reference 61). As part of this protocol, nonvolatile organics are extracted with methylene chloride from pH-adjusted water into two fractions: base-neutral components and acidic components. The acidic components specifically analyzed by EPA protocol are phenols, including penta. This extraction method may be subject to physical losses and difficulties from emulsions, but has been successfully applied to a variety of industrial effluents.

Two methods for the extraction of sludge are those of Renberg (Reference 59) and EPA (Reference 62). The former method involves shaking of solid material with sodium hydroxide solution. The diluted extract is then purified using the Sephadex anion exchange method previously described. The EPA method begins with air drying of the sludge followed by Soxhlet extraction of the acidified sample.

A.1.3 Gas Chromatography of Wood Preservative Effluent Extracts

Gas chromatographic analysis of phenols has commonly been conducted on columns such as OV-17 or Tenax GC (References 59 through 61). Neither of these systems is ideal, however. OV-17 yields no separation of phenols from nonpolar species, and Tenax GC often strongly adsorbs phenols and deteriorates after a few analyses. An improved phenol analysis method uses the deactivated polyester column SP1240DA. This gas chromatographic analysis yields good separation of alkyl- and chlorophenols and is now recommended by EPA.

An alternate method of phenol analysis involves conversion to methyl or pentafluorobenzyl (PFB) ethers, followed by gas chromatographic analysis on standard silicone columns (Reference 63). These derivatization methods allow for increased selectivity, improved gas chromatographic behavior and, for the PFB method, the increased sensitivity of electron capture detection. These methods, however, involve a more lengthy preparation and the use of hazardous chemicals.

PAH's are readily extracted from aqueous samples or solids with organic solvents. They are, however, very strongly adsorbed to carbonaceous solids. Analyses of complex mixtures of PAH's are best conducted with capillary column gas chromatography/mass spectrometry (GC/MS). When a limited number of polynuclear species need to be determined, as in the present case, packed column GC/MS may be sufficient (References 64 through 66).

Polychlorodibenzofurans and polychlorodibenzo-p-dioxins are known to be contaminants of technical grade penta. Analyses of these materials are based on solvent extraction, extensive chromatographic cleanup, and gas chromatography with electron capture detection (GC/EC) (Reference 67). Extremely sensitive and reliable analyses use mass spectrometers in the selected ion monitoring mode (Reference 68).

A.2 CHARACTERIZATION OF WOOD PRESERVING WASTEWATERS

Samples of wastewater from operating preservation plants were collected and analyzed by several analytical techniques. A discussion of those techniques and the results are given in the following sections.

A.2.1 Penta Wood Preserving Wastewater Characterization and Evaluation of Wastewater Extraction Methods

Penta wood preserving wastewater from the oil-water separator was used to compare various acid extraction methods. The wastewater samples were obtained from a typical Boulton conditioning plant (Figure A-1) which is identified as Plant A. The three methods evaluated were:

- Acidification of the wastewater to pH 1.0 and extraction with dichloromethane. This extract contains acidic species and neutral species.
- The Amberlite A-26 ion exchange method using an anion exchanger to isolate acidic species
- The XAD-2 adsorption method to isolate all nonpolar species from an acidified water sample

Details of these three methods are contained in Section A.4.2.

Each of these methods yielded an extract heavily contaminated with hydrocarbons. It was possible to distinguish the penta peak on gas chromatographic analysis, and Table A-1 shows the results for multiple analyses with each method. Initial fears that wood preserving wastes would yield intractable emulsions on attempted solvent extraction were unfounded for this sample. The acid neutral method yielded the best results. Spiking of a separate water aliquot with penta at 3.2 mg/liter and reextraction, yielded a recovery of 101 percent.

Gas chromatographic/mass spectrometric analysis of the acid-neutral extract (Figure A-2) yielded the results for a wastewater sample (collected from an operating wood treating plant), listed in Table A-2. This sample was not analyzed for volatile organics. The wastewater sample was also analyzed for the presence of polychlorodibenzo-p-dioxins (PCDD's). Using the method described in Section A.4, based on alumina cleanup of the acid/neutral extract followed by gas chromatography with electron capture detection, octachlorodibenzo-p-dioxin (OCDD) was detected at a concentration of 1.2 g/liter. This peak was indistinguishable from authentic OCDD by coinjection on the gas chromatograph (Figure A-3). No attempt was made to confirm the identification of this peak using mass spectroscopy. The recovery of OCDD through the alumina column cleanup was tested with the authentic standard at a level of 200 ng. The average recovery as measured by GC/EC was 110 percent for three experiments.

About 1 month after the initial analysis of this wastewater, during the course of the pan evaporator simulations described later, the analysis of OCDD on this wastewater was repeated. Using the same methodology, no trace of this material was found to a detection limit of 100 ng/liter. Six months later, this same sample was submitted to Professor Tiernan of Wright State University for OCDD analysis using more reliable mass spectral methods. Dr. Tiernan was

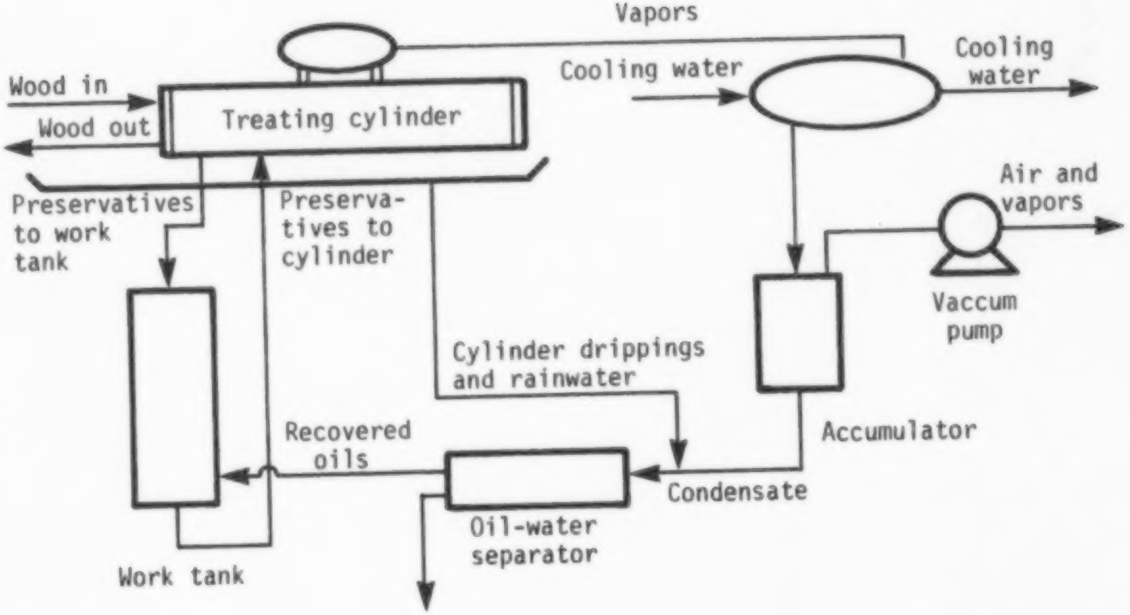

Vapors
Wood in
Wood out
Treating cylinder
Cooling water
Cooling water
Air and vapors
Preservatives to work tank
Preserva-tives to cylinder
Vaccum pump
Cylinder drippings and rainwater
Accumulator
Recovered oils
Condensate
Oil-water separator
Work tank

Figure A-1. Diagram of a Boulton process wood treating plant.

TABLE A-1. COMPARISON OF THREE ACID EXTRACTION METHODS

Method	Penta found (μg/l)	Number of determinations
Acid neutral extraction	870	6
A-26 ion exchange	620	2
XAD-2 adsorption	670	2

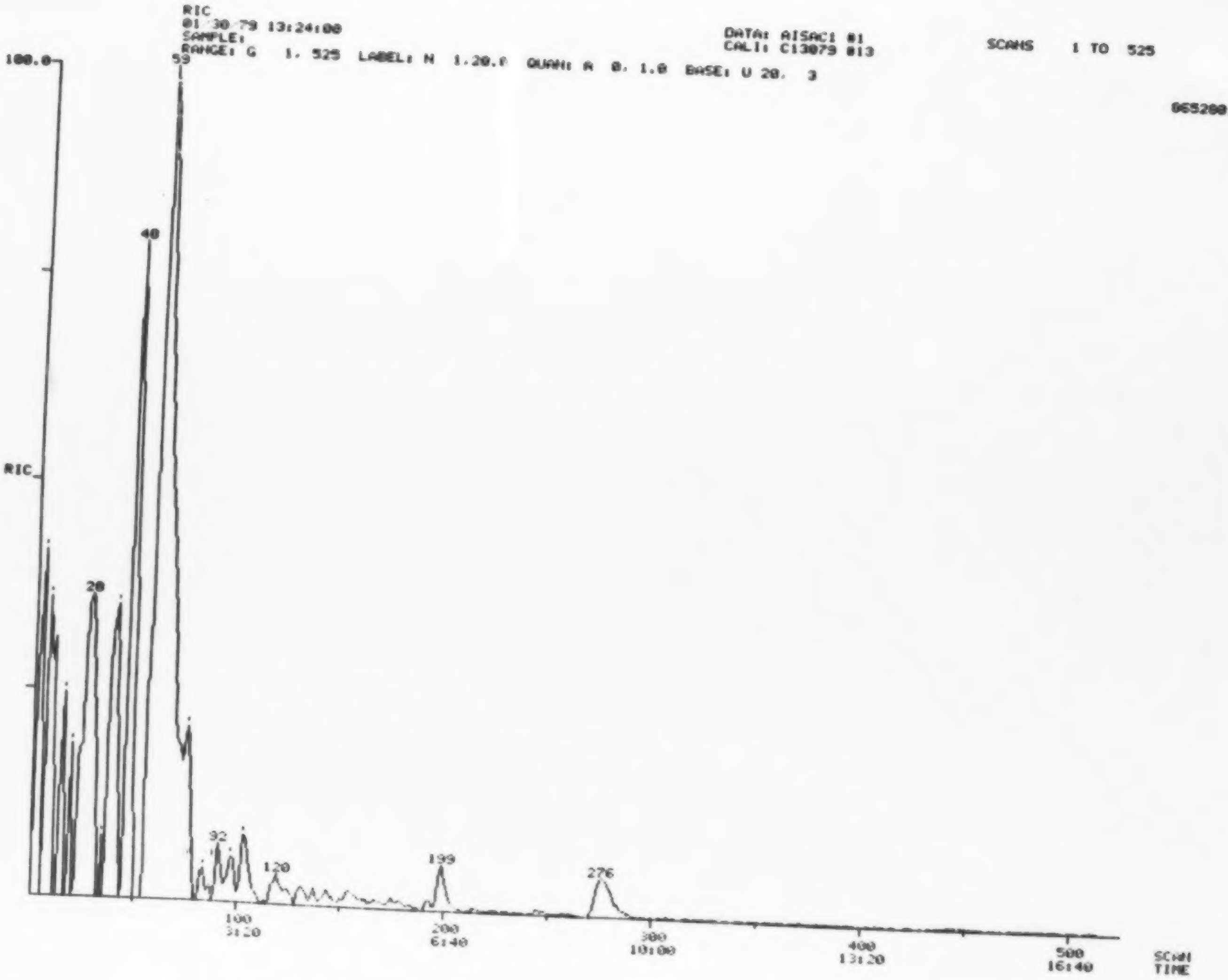
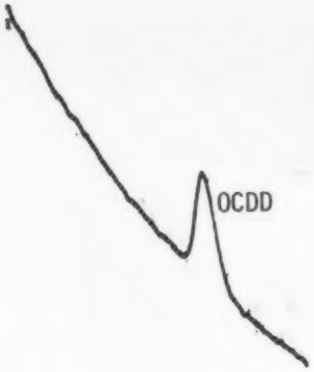


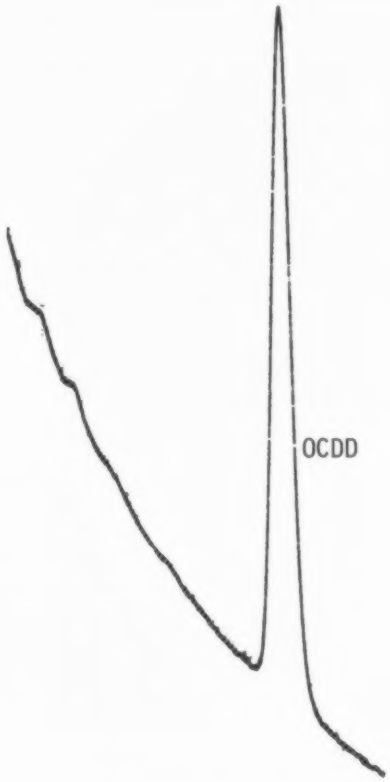
Figure A-2. Total ion current chromatogram of GC/MS analysis of acid/neutral extract of Plant A wastewater.

TABLE A-2. CONSTITUENTS OF WASTEWATER FROM A WOOD TREATING PLANT

Compound	Concentration ($\mu g/l$)
Penta	870
Tetrachlorophenol (isomer unknown)	100
2,4,6-Trichlorophenol	50
Phenol	50
Naphthalene	50



Putative OCDD peak



Coinjection with authentic OCDD

Figure A-3. GC/EC chromatograms of Plant A wastewater extract.

unable to detect OCDD to a stated sensitivity of 600 ng/liter. The descrepancies in these results are ascribed to one of the following:

- The originally present OCDD was lost to adsorption on the glass container during storage or photocomposition

- The originally observed chlorinated compound was not OCDD

Further research, with freshly collected samples, will be necessary to resolve this question.

Wastewater was analyzed for classical parameters after storage as indicated in Table A-3. This information is presented for informational purposes only and to allow for comparison to other wastewaters reported by the industry.

A.2.2 Characterization of Creosote Wood Preservative Wastewater

A sample of wastewater was obtained from a second Boulton conditioning wood preserving facility (identified as Plant B) that uses creosote. A 1-liter aliquot of this sample was extracted to yield base/neutral and acid fractions as described in Section A.4. Packed column GC/MS analyses of these fractions gave the results indicated in Figures A-4 and A-5 and Table A-4.

Due to the complexity of the base/neutral extract, this sample was analyzed by capillary column GC/MS. This method allowed for the identification of over 75 compounds in the complex mixture. As shown in Table A-5, many of these compounds are isomeric alkylaromatics and alkylheteroaromatics. Without comparison to authentic standards, it is impossible to assign precise structures to these species.

Figure A-6 shows the total ion current chromatrogram for the capillary analysis. The complexity of this mixture exceeds even the resolving power of the capillary gas chromatographic technique. Part of the complexity of the sample is due to the presence of phenol and several alkylphenols. Other workers have noted the crossover of weak acids into a base/neutral extract (Reference 70). A careful separation of creosote wastewater into basic, acidic, and neutral extractables would be a necessary prerequisite to a more thorough examination of this coaltar-derived mixture. Such an undertaking was outside the scope of this project.

As the PAH's were to be the major focus of this study, an experiment was conducted to test the recovery of these species from spiked wastewater. The four compounds listed in Table A-6 were spiked into a 1-liter sample and extracted as usual. GC/MS analysis indicated the recoveries shown in the table. The only explanation for the poor recovery of naphthalene was a volatilization loss during extract concentration. No attempts were made to improve the naphthalene recovery since the qualitative purposes of this study did not require it. A further difficulty in the PAH determination was the high suspended solids content of these samples. As noted in Table A-4, very poor reproducibility was obtained in multiple analyses of this sample.

TABLE A-3. PLANT A CLASSICAL ANALYSIS[a]

pH Parameter	Concentration as received (mg/l)
Total phenols	1.9
Oil and grease	17
Chemical oxygen demand	2,300
Total suspended solids	10
Total dissolved solids (180°)	73

[a] Analytical methods as described in Reference 69.

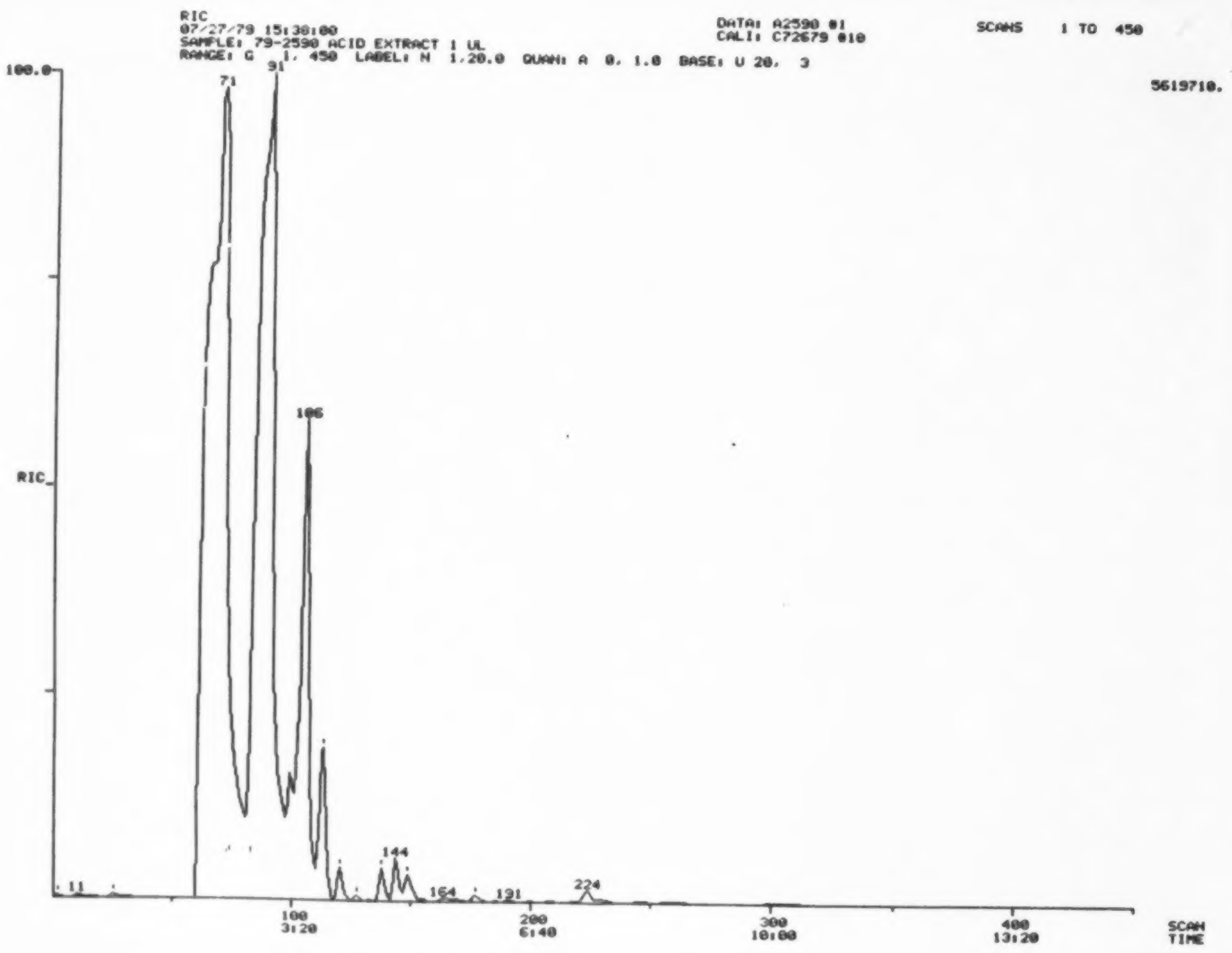


Figure A-4. Total ion current chromatogram of acid extract of Plant B wastewater.

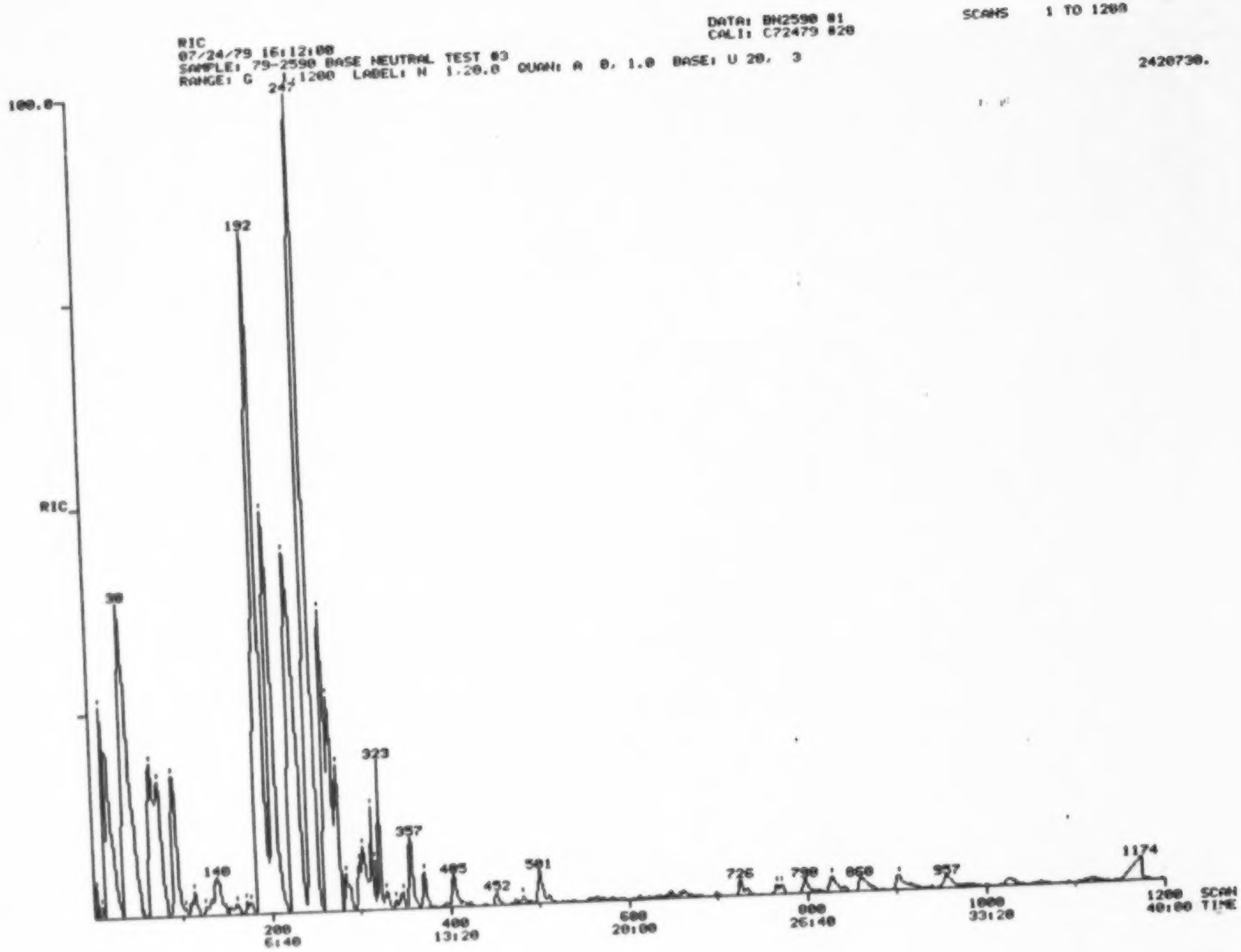


Figure A-5. Total ion current chromatogram of base/neutral extract of Plant B wastewater: packed column GC/MS.

TABLE A-4. ORGANICS DETECTED BY PACKED COLUMN GC/MS OF BASE/NEUTRAL AND ACID EXTRACTS OF CREOSOTE WASTEWATER FROM PLANT B

Compound	Concentration[a]
Naphthalene	54,000 (30,000)
Acenaphthene	14,100 (11,000)
Fluorene	5,000 (1,800)
Phenanthrene/Anthracene[b]	2,100 (850)
Fluoranthene	270 (77)
Pyrene	170 (73)
Chrysene/Benz(a)anthracene[b]	96
Benzo(a)pyrene isomers[b]	10
Benzo(j/k)fluoranthene[b]	50
Phenol	10,000
Methylphenols (isomers not resolved)	10,000
C_2-Alkylphenols (isomers not resolved)	4,000
C_3-Alkylphenols (isomers not resolved)	1,000
Benzoic Acid	500

[a] Concentrations in μg/liter. Polynuclear aromatic quantitations based on four determinations. Acid quantitations are rough estimates only. The numbers in parentheses are standard deviations for the multiple determinations of PAH.

[b] These isomeric pairs are not resolved by packed column gas chromatography.

TABLE A-5. ORGANICS DETECTED BY CAPILLARY GC/MS OF BASE/NEUTRAL EXTRACT OF CREOSOTE WASTEWATER

Compound	Number of resolved isomers	Compound	Number of resolved isomers
Styrene	1	Naphthalene[a]	1
Pyridine	1	Methylnaphthalenes[a]	2
Methylpyridines[a]	3	C_2-Alkylnaphthalenes	5
C_2-Alkylpyridines[a]	6	C_3-Alkylnaphthalenes	2
C_3-Alkylpyridines	5	C_4-Alkylnaphthalene	1
C_4-Alkylpyridines	3	Quinoline[a]	2
C_2-Alkylbenzene (probably p-xylene)	1	Methylquinoline	5
		C_2-Alkylquinoline	3
C_3-Alkylbenzene	2	C_3-Alkylquinoline	1
Benzaldehyde	1	Indole	1
Benzofuran	1	Biphenyl	1
Acetopyridine	1	Methylbiphenyl	3
Indane	1	C_2-Alkylbiphenyl	1
Indene	1	Acenaphthene[a]	1
Phenol	1	Dibenzofuran	1
Methylphenols[a]	3	Methyldibenzofuran	2
C_2-Alkylphenols[a]	5	Fluorene	1
C_3-Alkylphenol	1	Methylfluorene	2
Acetophenone	1	Dibenzothiophene	1
Benzonitrile	1	Anthracene	2
Methylbenzonitrile	1	Carbazole	1
Methylindenes	2		
Methylacetophenone	1		

[a] Indicate the major species -- no quantitation of these species was attempted.

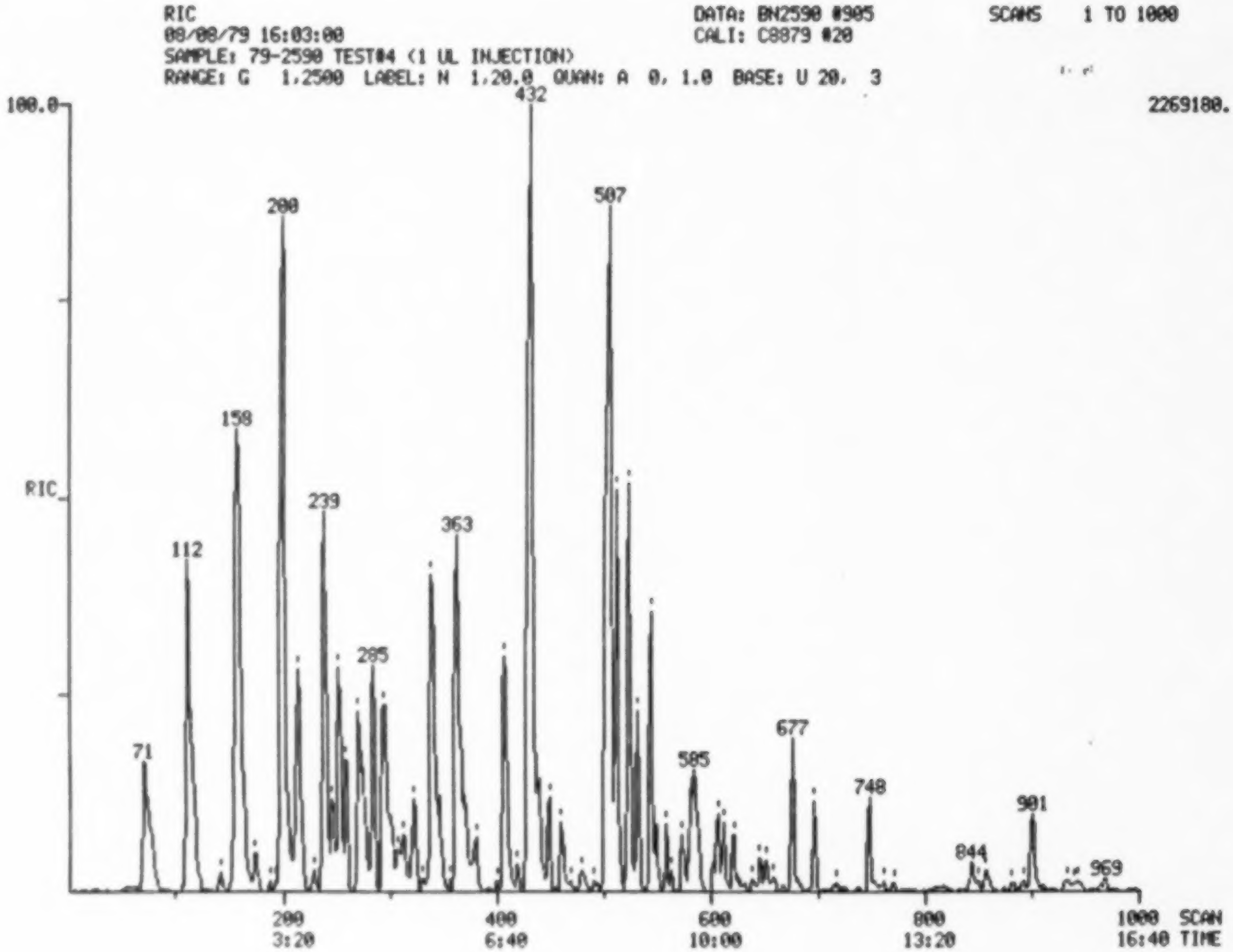


Figure A-6. Total ion current chromatogram of base/neutral extract of Plant B wastewater: capillary GC/MS.

TABLE A-6. RECOVERY OF PAH's FROM CREOSOTE WASTEWATER[a]

Compound	Spike level (μg/L)	Percent Recovery
Naphthalene	80,000	34
Fluorene	4,000	100
Phenanthrene	2,000	86
Pyrene	2,000	83

[a] Average of two determinations

Results for classic parameter analysis of the creosote wastewater are noted in Table A-7. The analyses were conducted after storage.

A.3 EVALUATION OF AIR SAMPLING METHODS

The polymeric adsorbent XAD-2 was chosen to be used in pan evaporator tests and field sampling of airborne emissions. Prior to its use in experiments, the XAD-2 air sampling cartridge was tested for recoverability of spiked compounds. The type of XAD-2 cartridge used throughout this study is shown in Figure A-7. The cartridge holds 60 grams of resin (cleaned prior to use as described in Section A.4) held in place with plugs of glass wool. The fresh cartridge is placed in an air sampling train (Appendix B) or pan (thermal) evaporator test apparatus (Section A.5). At the end of the test period, the organics are recovered from the XAD-2 resin by Soxhlet extraction using the special apparatus shown in Figure A-8.

The compounds listed in Table A-8 were spiked onto an XAD-2 cartridge and recovered by Soxhlet extraction with 15 percent ethyl ether in hexane for 16 to 24 hours. Compound recoveries were measured with the gas chromatography/flame ionization detector (GC/FID) methods described in the following section. The recoveries found were all greater than 70 percent. Variations from 100 percent indicate losses during extract concentration and GC measurement error more than any retentive characteristic of the XAD-2.

A final experiment was conducted to test for volatilization losses of penta during test conditions. XAD-2 cartridges were spiked with 20 μg of penta, and laboratory air was drawn through the cartridge for 1 hour at 0.6 ft^3/min. Recovery was determined as before. In four trials, the penta recovery was 96 ±8 percent.

A.4 ANALYTICAL PROCEDURES

Methods of analysis and instruments are described in the following sections for various process waste sampled, pollutant constituents, and waste type studied. Procedures, conditions, and equipment are detailed.

TABLE A-7. CLASSICAL ANALYSES OF CREOSOTE WASTEWATER[a]

Sample	As received
Total phenols	570
Oil and grease	2.9
Chemical oxygen demand	5,500
Total suspended solids	4
Total dissolved solids	52

[a] All values in mg/liter. Analytical methods as described in Reference 69.

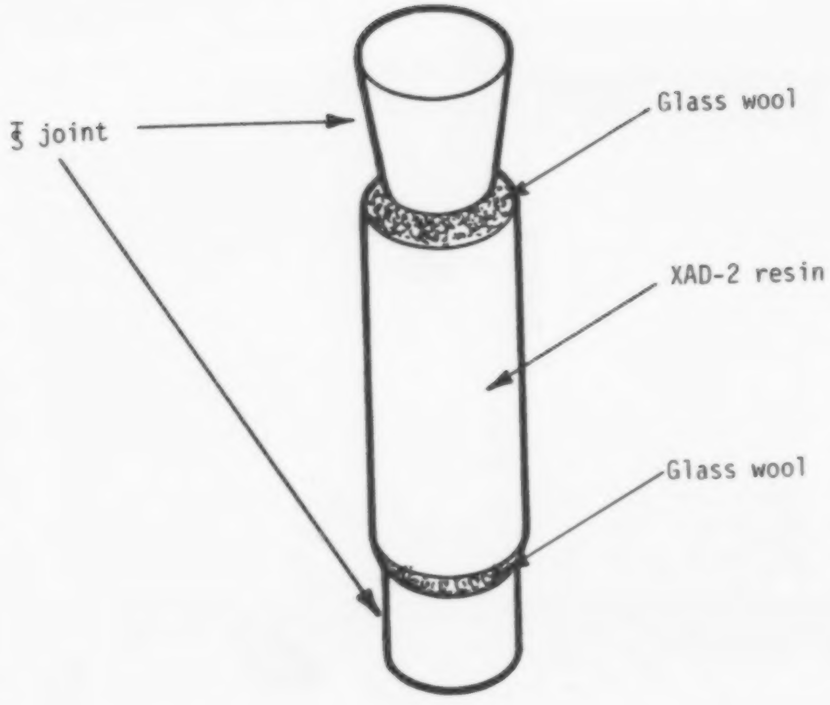

$\overset{\mathrm{T}}{\mathrm{S}}$ joint
Glass wool
XAD-2 resin
Glass wool

Figure A-7. XAD-2 cartridge used to sample airborne pollutants.

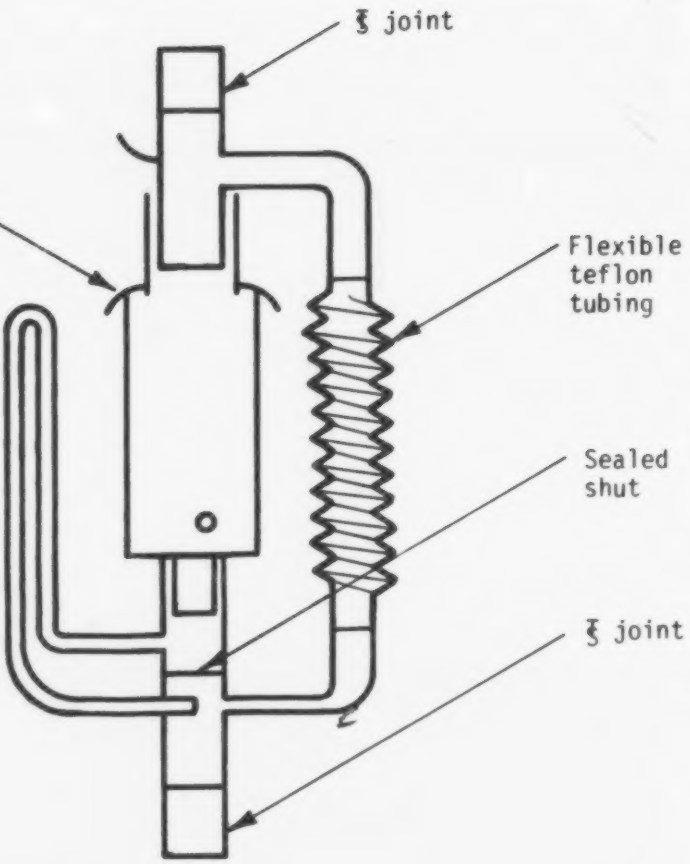

§ joint
XAD cartridge
Flexible teflon tubing
Sealed shut
§ joint

Figure A-8. Apparatus for Soxhlet extraction of XAD-2 cartridges.

TABLE A-8. RECOVERY OF PHENOLS AND PAH's FROM XAD-2 RESIN

Compound	Spike level (μg)	Percent recovery
2,4,6-Trichlorophenol	20 200	74 94
Penta	20 200	110 100
Naphthalene	27,000	72
Phenanthrene	23,000	81

A.4.1 Materials and Instrumentation

All solvents used in this project were Mallincrodkt "Nanograde" or equivalent. Anhydrous sodium sulfate was heated at 450°C for 6 hours prior to use. Amberlite XAD-2 resin (Rohm and Haas) was cleaned by successive overnight Soxhlet extractions with water, methanol, and methylene chloride (twice). The cleaned XAD-2 was dried at room temperature prior to packing it in cartridges. Authentic standards of organic compounds were obtained from Chem Service Corporation and RFR Corporation.

GC/MS was conducted with a Finnegan Model 4023 GC/MS/DS system. A Perkin-Elmer Sigma I gas chromatograph with either electron capture or flame ionization detection was also used.

A.4.2 Wastewater Extraction Methods

Extraction methods used for wastewater included ion exchange, resin adsorption, and base-neutral organic extractions.

A.4.2.1 A-26 Ion Exchange Method for Phenols

The wastewater sample (100 ml) was treated with sodium hydrosulfite (20 mg) and adjusted to pH 12 with 2 M NaOH. It was then placed on a 1/2- x 5-inch prepared column of Rohm and Haas A-26 anion exchange resin (Reference 60). The column was eluted with basic methanol and water. These eluates were discarded. The acidic species were then eluted with aqueous hydrochloric acid followed by aqueous acetone. The combined eluates were back extracted with dichloromethane, dried (sodium sulfate), and concentrated to 1.0 ml for analysis.

A.4.2.2 XAD-2 Adsorption Method

The water sample (100 ml) was acidified to pH 1.0 with 6 N HCl and passed through a short (5- by 1.5-cm) column of XAD-2 (40,60 mesh) at a flowrate of 2 ml/min. The organics were then eluted with 50 ml of diethyl ether. The extract was concentrated to 1.0 ml in a Kuderna-Danish evaporator prior to analysis.

A.4.2.3 Base-Neutral/Acid Extraction

A water sample (100 ml) was basified to pH 11 with 6 N NaOH and extracted with three 60-ml portions of dichloromethane. This base-neutral extract was saved for analysis of hydrocarbons or discarded. The aqueous layer was then acidified to pH 1.0 with 6 N HCl and extracted with three 60-ml portions of dichloromethane. This extract was concentrated to 1.0 ml prior to analysis.

A.4.3 Extraction of Solid Samples and Sludges

XAD-2 cartridges from pan evaporator tests or field samplings were extracted using the apparatus shown in Figure A-8. Solvent (15 percent ethyl ether in hexane) was cycled for 16 hours. The dried (sodium sulfate) extract was then concentrated to 1.0 ml with a Kuderna-Danish evaporator. Filter cake samples and dry sludges were extracted in a similar manner. Wet sludges were mixed with a tenfold amount of granular anhydrous sodium sulfate prior to Soxhlet extraction as previously described.

A.4.4 Cleanup of Soxhlet Extracts for Phenols

The sample extract was reconstituted with hexane to 100 ml. The acidic species were then extracted with three 30-ml portions of 0.1 N sodium hydroxide. The combined basic extracts were backwashed once with 20 ml of hexane. They were then acidified to pH 1.0 with 1 N hydrochloric acid and extracted with three 30-ml portions of dichloromethane. The combined, dried (sodium sulfate) extracts were then concentrated to 1.0 ml.

A.4.5 Cleanup of Extracts for Analysis of Polychlorodibenzo-p-dioxins

Sample extracts (base-neutral, acid-neutral, or Soxhlet extracts) were solvent exchanged to benzene and placed on a short column of alumina (ICN aluminum oxide W200 basic, activity grade Super I) (Reference 67). The column was eluted with 10 ml of 2 percent dichloromethane in hexane. The desired compounds were then eluted with 10 ml of 50 percent methylene chloride in hexane. The solvent was evaporated to less than 2 ml in a micro-Kuderna-Danish concentrator, solvent exchanged to benzene and taken to a final volume of 1.0 ml.

A.4.6 Determination of Phenols

Determination of phenols (especially penta) was conducted by gas chromatography on the deactivated polyester phase SP1240DA. Initial sample characterization used GC/MS for identification of acidic species. The gas chromatographic conditions for analysis of phenols are listed in Table A-9. The GC/MS conditions are shown in Table A-10.

The majority of the qualitative identification and all of the quantitation of penta was conducted by GC/FID. Prior to analysis, the linear response range for penta was shown to be 50 to 2000 ng injected. Samples were diluted to fall in this range. In every tenth sample, the response factor was confirmed by analysis of a penta standard. The most important factor in reliable penta analysis was column condition. It was necessary to repack the front end of the SP1240DA column at regular intervals.

A.4.7 Determination of PAH's

The complexity of the creosote wastewater necessitated the use of GC/MS for all PAH analyses. The GC column was 3 percent SP2250DB. The GC operating conditions were as shown in Table A-11.

Prior to injection, each sample was spiked with d_{10}-anthracene as internal standard. Quantitation was based on relative response factors of specific quantitation ions. Table A-12 lists the specific ions used in this study along with the relative response factors and standard deviations of the response factors found during the course of this study.

A.4.8 Sample Cleanup and Determination of Octachlorodibenzo-p-dioxin

Neutral (or acid-neutral) extracts of penta wastewater or sludge were analyzed for the presence of polychlorinated dibenzo-p-dioxins using the method of Mieure, et al. (Reference 67). Determination of polychlorinated dibenzo-p-dioxins was conducted at Acurex using GC/EC with the operating conditions shown in Table A-13.

A.5 PAN EVAPORATOR TEST APPARATUS AND METHODS

The initial pan evaporator simulations (penta wastewater Tests 1 through 4 and creosote Test 1) were conducted using the test apparatus shown in Figure A-9. This apparatus consisted of a stainless steel pan and heating mantle enclosed by a painted metal stack. The dimensions of the pan were 12 by 9.5 in. The stack was 4 in. in diameter and 50 in. tall. An inverted funnel was placed at the top to direct the rising vapors into the vacuum system. The XAD-2 cartridge was connected to the funnel by all-glass adaptors. An ice-cooled flask located after the cartridge, collected the condensed water vapor. A silica-gel trap protected the vacuum pump.

The step-by-step operating procedure for the pan evaporator is shown in Table A-14. At a temperature of 70° to 80°C, a test could be completed in about 5 to 6 hours. The results of the tests are discussed in the following section.

A serious problem occurred with the initial test apparatus when a large amount of water condensed inside the stack and could not be recovered. In addition, leaks were always seen at the top of the stack. The apparatus was large and unwieldly. The tests of potentially toxic airborne chemicals had to

TABLE A-9. CONDITIONS FOR GC ANALYSES OF PHENOLS

Column:	4' x 1/4" glass column packed with 1 percent SP1240DA on 100/120 mesh Supelcoport
Injector:	200°C
Temperature program:	80°C for 1.5 min. Program at 10°/min to 180°C
Special Note:	Columns were rinsed with 3 percent phosphoric acid in acetone prior to packing. Glass wool was phosphoric acid treated.

TABLE A-10. MASS SPECTROMETER OPERATING CONDITIONS FOR DETERMINATION OF PHENOLS AND PAH's

Separator temperature:	265°C
Electron energy:	70 eV
Mass range:	45 to 475 a.m.U.
Scan time:	2 sec
Source tuning:	DFTPP (see Reference 71)

TABLE A-11. OPERATING CONDITIONS FOR ANALYSIS OF PAH's

Column:	6' x 1/4" glass column packed with 3 percent SP2250DB on 100/120 mesh Supelcoport
Injector:	275°C
Temperature program:	50°C for 1.5 min. Then program at 8°/min to 270°C

TABLE A-12. GC/MS QUANTITATION IONS AND RELATIVE RESPONSE FACTORS USED FOR DETERMINATION OF PAH's

Compound	Quantitation ion (m/l)	Relative response factor (to d_{10}-anthracene)	Standard deviation
Naphthalene	128	0.98	0.18
Acenaphthene	154	0.67	0.13
Fluorene	166	0.67	0.23
Phenanthrene/anthracene	178	1.03	0.19
Fluoranthene	202	1.18	0.08
Pyrene	202	1.20	0.09
Chrycene/ benz(a)anthracene	228	0.67	0.07

TABLE A-13. GAS CHROMATOGRAPHIC OPERATING CONDITIONS FOR THE DETERMINATION OF OCTOCHLORODIBENZO-P-DIOXIN

Column:	6' x 1/4" glass column packed with 3 percent OV210 on Gas Chrom Q
Injection temperature:	250°C
Column temperature:	Isothermal at 230°C
Carrier gas:	5 percent methane in argon at 20 ml/min

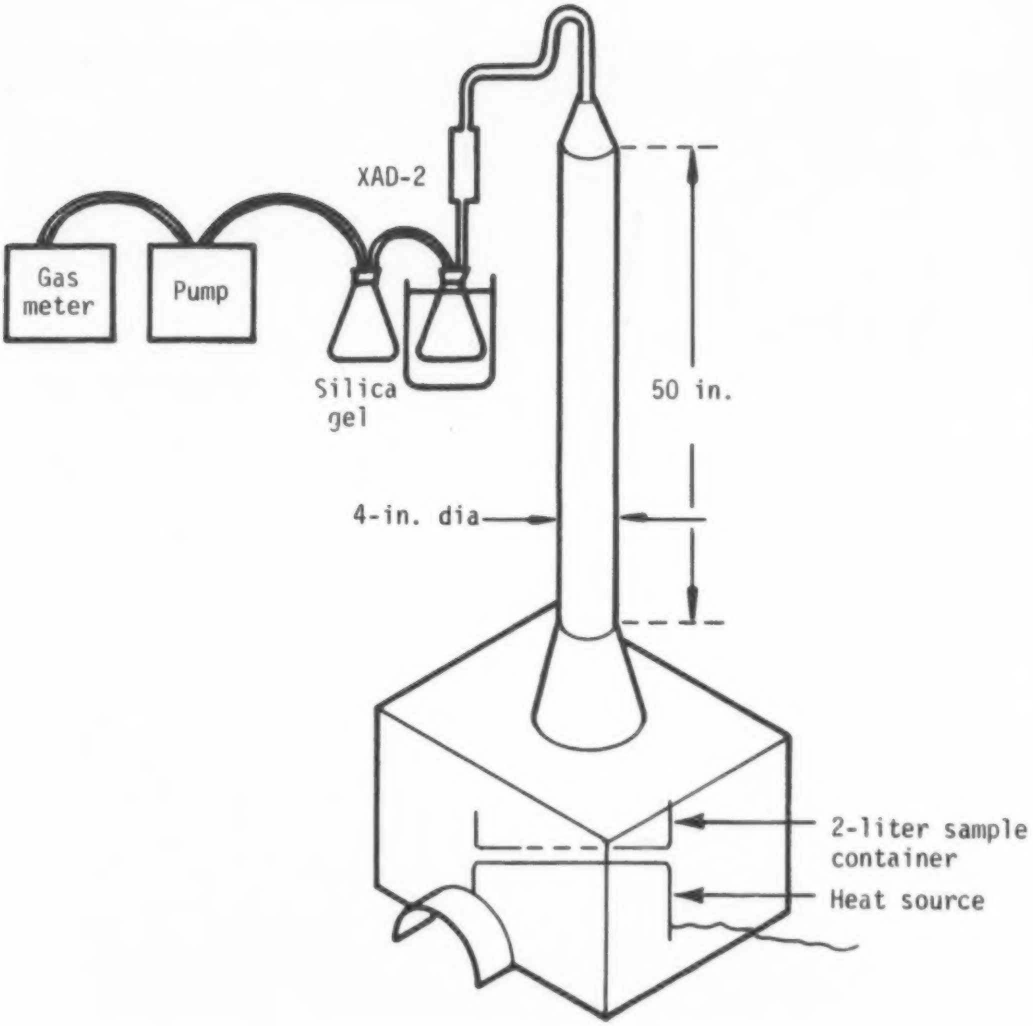

XAD-2
Gas meter
Pump
Silica gel
50 in.
4-in. dia
2-liter sample container
Heat source

Figure A-9. Pan evaporator test apparatus 1.

TABLE A-14. PAN EVAPORATOR TEST PROCEDURE

Apparatus 1

1. Wastewater (2.0 liters) was adjusted to the appropriate pH with 6 N HCl or solid calcium hydroxide, and charged to the pan
2. The hotplate was turned on and the temperature regulated to the test temperature
3. When the test temperature was reached, the pump was turned on and adjusted to draw 0.5 cfm
4. At hourly intervals the pump was shut off and the XAD-2 cartridge changed
5. When the water had all evaporated, the system was shut down, cooled, and any sludge remaining in the pan was scraped into a bottle
6. All samples were extracted and analyzed as described previously

Apparatus 2

1. Wastewater (500 ml) was pH-adjusted with 6 N HCl or solid calcium hydroxide. The suspension was filtered through Whatman 541 filter paper directly into the 1-liter round bottom flask.
2. The apparatus was assembled and the heating rate was adjusted to maintain the flask at 60° to 90°C. The pump was then turned on and the flowrate adjusted to 0.5 cfm.
3. As the evaporation proceeded, the water was collected in the ice-cooled trap. The XAD-2 trap was changed at rough intervals so that each trap would represent one-third of the evaporation.
4. When evaporation was complete, the connecting tubes were rinsed into the round bottom flask with dichloromethane to be treated as sludge.
5. The filter paper and cake were air-dried prior to Soxhlet extraction.
6. The evaporation residue was rinsed extensively with dichloromethane. The sludge was normally a surface residue only so no Soxhlet extraction was necessary.
7. The XAD-2 cartridges were Soxhlet extracted as described in Section A.4

be conducted in a walk-in hood with special safety precautions for the operator. Finally, the results using this apparatus (see Section A.6) indicated a variable recovery of input chemicals. Clearly, a better enclosed test system was needed.

The modified test apparatus is shown in Figure A-10. This apparatus was used for penta Tests 5 and 6 and creosote Tests 2 through 4. This all-glass system was totally enclosed and could be easily handled in a standard hood. At the conclusion of a test, the glass parts could be disassembled and rinsed to recover all materials. In addition, a filtration step was added to the procedure to test the effect of pH on removal on insoluble components. Table A-14 lists the procedures used with the second apparatus.

A.6 TEST RESULTS

Ten tests were run on penta and creosote wastewaters. Both pH and equipment were changed during the series of testing.

A.6.1 Penta Evaporation Tests

The major compounds of concern in the penta wastewater were penta and OCDD's. In the first set of pan evaporator tests, only these species were determined. Table A-15 shows the results for penta evaporation in the first test series. These tests did not include a filtration step. The pH-adjusted wastewater was changed directly into the pan. As shown in Table A-15, these test conditions lead to penta emissions at all initial pH levels.

The low and variable penta recovery evident in the data of Table A-15 is probably due to the design of the test apparatus. During evaporation, water would condense in the stack, drip down, and not be recovered. Also, vapor leaks were noticed at the stack/funnel junction. For these reasons an improved test apparatus was used for later tests.

The amount of sludge generated in each test is listed in Table A-16. These weights are crude as no attempt was made to dry these sludges to constant weight. Each sludge was dissolved in dichloromethane and analyzed for OCDD as described previously. The results (Table A-16) indicated the presence of OCDD in each sludge.

Based on these numbers, the total sludge OCDD varied from 13 ng (Test 1) to 660 ng (Test 4). The crude nature of these numbers does not allow for any conclusions to be drawn on the differences in sludge OCDD content. However, as the wastewater was shown (Section 4) to contain 1.2 g/liter OCDD, the OCDD recovered from the sludge is appreciably less than the calculated input from a 2-liter wastewater sample. Furthermore, no OCDD was detectable in any of the Test 1 XAD-2 cartridges.

In light of the difficulties encountered in the initial test set, a second set of penta evaporations were conducted. These two experiments used the all-glass evaporation apparatus as described in Section A.5. The wastewater charge was obtained from samples collected at Plant C. These

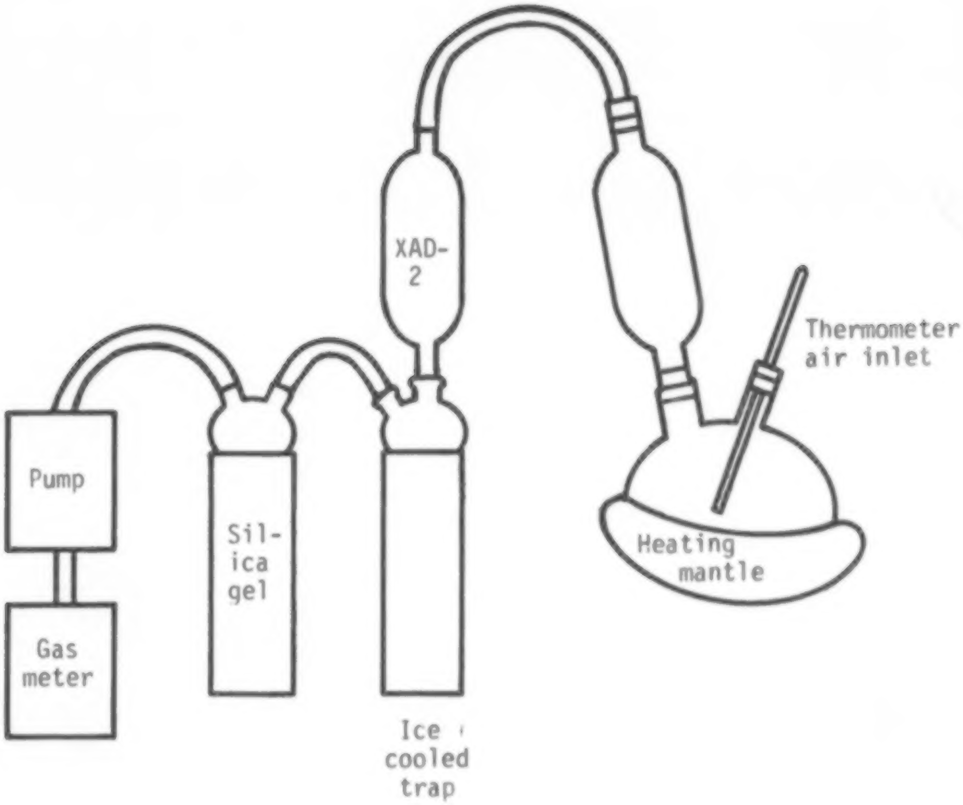

XAD-
2
Thermometer
air inlet
Pump
Sil-
ica
gel
Heating
mantle
Gas
meter
Ice
cooled
trap

Figure A-10. Pan evaporator test apparatus 2.

TABLE A-15. PAN EVAPORATION TESTS WITH PENTA WASTE EFFLUENT

	Test 1 -- pH unadjusted ~4.5			Test 2 -- pH 10			Test 3 -- pH 2			Test 4 -- pH 12		
Elapsed time (hrs)	Water temp °C	Air vol ft^3	μg penta	Water temp °C	Air vol ft^3	μg penta	Water temp °C	Air vol ft^3	μg penta	Water temp °C	Air vol ft^3	μg penta
1	81.5	39.4	322	78.5	39.0	124	81.5	40.3	196	90.0	47.0	1110
2	80.5	40.0	488	74.5	34.8	174	79.5	39.6	157	86.4	51.2	12
3	81.0	38.2	324	72.0	38.5	89	80.4	41.8	97	87.2	44.8	35
4	86.0	41.8	28	80.0	40.4	316	84.5	40.8	[a]	89.2	51.4	65
5				--	29.0	65	92.1	42.2	208		35.9	34
6							--	46.8	192			
Total		159.4	1160		181.7	770		251.5	851		230.3	1260
% recovery of applied penta			66			44			48			72

[a] XAD-2 cartridge not changed

NOTE: No penta detected in either hexane or methylene chloride extracts of sludge samples are described more fully in Appendix B. They were much more concentrated in penta and contained a large amount of oil.

The wastewater was pH-adjusted and filtered prior to evaporation. Since the possibility of the organic adsorbed onto solid particles, each solution was filtered to prevent breakdown and subsequent release of the organics from the matrix. As shown in Table A-17, the filtration removed the majority of the penta in the acidified sample. In the test at pH 12 (Test 6) the penta stayed in solution and was largely volatilized during the test. In both tests, good recoveries of applied penta were obtained. No attempts were made to analyze this wastewater or test samples for OCDD.

A.6.2 Creosote Evaporation Tests

Only the major PAH's were quantitated in tests using creosote wastewater from Plant B.

Test 1 was conducted using apparatus 1. The recovery of PAH was very poor in this test (Table A-18). The volume of water recovered from the impinger trap was less than 20 percent of the charged wastewater. For these reasons, this apparatus was abandoned. Tests 2 through 4 were conducted with the all-glass apparatus (Figure A-10). Apparatus 2 gave better, but variable, data for Tests 2 through 4. This high particulate content of the creosote sample (see Section A.3) led to difficulty in obtaining representative and reproducible samples. As each sample was taken for charging to the evaporator, an aliquot from the same container was set aside for extraction. As noted in Tables A-18 through A-21, the measured concentrations of PAH varied considerably from sample to sample.

The results indicate that, independent of pH, a large percentage of the PAH's were removed by filtration. Those that remained in the change to the evaporation device were largely volatilized. The remaining residue contained very low or no amounts of PAH's.

Due to the difficulty in sampling and the poor recovery of naphthalene from spiked creosote (Section A.3), the results in Tests 2 through 4 are of qualitative value only. However, even with this limitation, several conclusions can be drawn:

- A large percentage of the PAH's (especially those heavier than naphthalene) are associated with the particulate phase of the creosote wastewater. These amounts are removable by filtration.
- The soluble PAH content of the wastewater is volatilized under the test conditions with temperatures greater than 60°C and continuous air flow
- No effect of pH is discernible

The results of the tests are difficult to interpret due to the poor overall recoveries. However, the difference in recovery between naphthalene

TABLE A-16. OCDD ANALYSIS OF PAN EVAPORATOR SLUDGE SAMPLES

Test	Weight of sludge obtained (mg)	OCDD content (pg/mg)[a]
1	120	110
2	1800	55
3	1900	31
4	3300	200

[a] Penta concentration 870 μg/l

TABLE A-17. PAN EVAPORATION TESTS WITH PENTA WASTEWATER (mg)

						Elapsed time/XAD-2 penta concentration					
Avg. temp. (°C)	pH	Charge	Filter cake	Residue	Water being evaporated	0-4 hrs	4-8 hrs	8-12 hrs	Total emitted	Percent emitted from water	Percent recovery
70	2	197	165	3	29.0	14	1.2	1.6	16.8	58	94
90	12	475	1.5	2.7	470.8	112	127	197	436	93	93

Volume of wastewater evaporated -- 1 liter

TABLE A-18. CREOSOTE PAN EVAPORATOR TEST 1 (EVAPORATION TEMPERATURE 60°C, pH UNADJUSTED = 4.5) (mg)

Compound	Charge	Filter cake	Wastewater content	XAD-1 0-6 hrs	XAD-2 6-12 hrs	XAD-3 12-15 hrs	Total emitted	Percent emitted from wastewater	Sludge	Percent recovery
Naphthalene	59	3.0	56.	24	0.14	6.0	30.1	54	0.01	61
Acenaphthene	30	0.23	29.8	0.67	0.01	0.01	0.7	2	0.01	3
Fluorene	5.6	0.15	5.5	0.40	0.01	0.02	0.4	8	0.02	4
Phenanthrene/ Anthracene	2.2	0.10	2.1	0.12	0.01	0.08	0.2	10	0.01	4
Pyrene	0.10	0.02	0.1	0.01	0.01	0.01	0.03	30	0.01	40
Fluoranthene	0.17	0.03	0.1	0.01	0.01	0.01	0.03	30	0.01	23

TABLE A-19. CREOSOTE PAN EVAPORATOR TEST 2 (EVAPORATION TEMPERATURE 70°C, pH OF WASTEWATER 10 -- ADJUSTED WITH CALCIUM HYDROXIDE

Compound	Charge	Filter cake	Wastewater content	XAD-1 0-4 hrs	XAD-2 4-8 hrs (mg)	XAD-3 8-12 hrs	Total emitted	Percent emitted from wastewater	Sludge	Percent recovery
Naphthalene	27	--	27.	16	4.1	6.1	26.2	97	0.05	97
Acenaphthene	5.5	--	5.5	1.9	0.04	0.01	2.0	35	0.01	35
Fluorene	3.6	--	3.6	0.57	0.04	0.11	0.7	20	0.01	20
Phenanthrene/ Anthracene	1.6	--	1.6	0.37	0.11	0.14	0.6	39	0.01	39
Pyrene	0.14	--	0.14	0.06	0.03	0.02	0.1	79	0.01	79
Fluoranthene	0.18	--	0.18	0.08	0.03	0.02	0.1	72	0.01	72

No filter cake was taken on this test.

TABLE A-20. CREOSOTE PAN EVAPORATOR TEST 3 (EVAPORATION TEMPERATURE = 80°C pH OF WASTEWATER 2.0 (ADJUSTED WITH HYDROCHLORIC ACID (mg)

Compound	Charge	Filter cake	Wastewater content	X1 0-3 hrs	X2 3-5 hrs	X3 5-7 hrs	Total emitted	Percent emitted from wastewater	Sludge	Percent recovery
Naphthalene	14	4.6	9.4	5.9	1.2	2.9	10	100	0.01	104
Acenaphthene	4	1.3	2.7	0.096	0.002	0.002	0.3	100	0.002	41
Fluorene	1.8	0.80	1.0	0.096	0.002	0.010	0.1	10	0.002	51
Phenanthrene	0.60	0.48	0.12	0.079	0.016	0.060	0.16	100	0.002	106
Pyrene	0.065	0.10	--	0.004	0.002	0.002	--	--	0.002	160
Fluoranthene	0.12	0.15	--	0.004	0.002	0.002	--	--	0.002	130

TABLE A-21. CREOSOTE PAN EVAPORATOR TEST 4 (EVAPORATION TEMPERATURE 90°C, pH OF WASTEWATER 12 -- ADJUSTED WITH CALCIUM HYDROXIDE (mg)

Compound	Charge	Filter cake	Wastewater content	X1 0-2 hrs	X2 2-4 hrs	X3 4-6 hrs	Total emitted	Percent emitted from wastewater	Sludge	Percent recovery
Naphthalene	50	3.1	46.9	11.2	5.8	6.4	23.4	50	ND	52
Acenaphthene	3.7	1.2	2.5	0.29	0.008	ND	0.3	12	ND	40
Fluorene	1.6	0.74	0.9	0.090	0.010	0.012	0.1	12	ND	53
Phenanthrene	0.85	0.61	0.2	0.077	0.072	0.097	0.2	100	ND	100
Pyrene	0.16	0.19	--	ND	ND	ND	--	--	ND	120
Fluoranthene	0.085	0.12	--	0.002	0.002	ND	--	--	ND	150

ND -- None detected; detection limit 0.002 mg and the higher molecular weight PAH's may be due to the latter's condensation in the stack. Such condensed materials were not recovered in Test 1.

A.7 DISCUSSION

To assess the results given previously, the recovery factor for analysis, errors in sampling, and problems of the pan evaporator test apparatus are important considerations.

A.7.1 Sampling and Analysis Methodologies

During the course of this study, several methods were investigated for the extraction of penta from wastewater. Eventually, ion exchange, XAD-2 adsorption, and acid/neutral extraction were abandoned in favor of the standard method of cleanup by discarding a base/neutral extract and obtaining the penta in an acid extract. With this standard method, reliable quantitation of penta may be performed to levels of below 10 g/liter. The emulsified samples from two different wood processing operations presented no problem during solvent extraction.

For the analysis of PAH's from creosote, solvent extraction was found to be adequate but had poor reproducibility. The major problem was one of obtaining a representative sample of an oily, high-particulate content water sample.

The use of XAD-2 resin as a reliable method for the quantitative sampling of airborne organics has been confirmed. This method has been described several times previously in the literature and is now accepted practice.

Neither of the wastewaters described herein was completely characterized in this study. Volatile organics were not determined. Identifications of the large number of hydrocarbons present in the penta wastewaters were not attempted. The identification and quantitation of chlorinated compounds in the penta wastewater (including OCDD) were only dealt with briefly. A beginning was made toward the characterization of creosote wastewater using capillary GC/MS, but considerably more effort is needed to fully explore this complex mixture.

A.7.2 Pan Evaporator Simulations

The results of the pan evaporator tests will be discussed in terms of the major wastewater treatment processes: simulated filtration and evaporation. Table A-22 presents some physical properties of the compounds studied in this test program.

The concentrations of penta in wastewater from Plant A and PAH's in creosote wastewater from Plant B exceeded the solubility of these species in clean water. This condition is due, in part, to the presence of suspended oils or solids or both. Upon filtration of the creosote wastewater a large percentage of the high molecular weight PAH's are removed. Naphthalene is the

TABLE A-22. SELECTED PHYSICAL PROPERTIES OF WOOD PRESERVING COMPONENTS[a]

Compound	Boiling point (°C)	Vapor pressure	H_2O solubility (mg/l)
Penta	310(d)	1.1×10^{-4}	14 (20°)
Naphthalene	218	1 mm (53°C)	30
Phenanthrene	340	--	1.6 (15°C)

[a] Largely taken from Reference 72.

most water-soluble of the PAH's and remained largely in solution. Penta is readily removed by filtration at an acidic pH. However, in basic solution, penta anion is quite soluble.

The results of the pan evaporation tests would indicate that all of the organics tested are volatilized during the evaporation of wastewater below the boiling point of water. The experimental difficulties encountered in the tests make quantitative calculations of evaporation rates difficult.

APPENDIX B

COOLING TOWER FIELD TESTING PROGRAM

B.1 PROGRAM DESCRIPTION

The purpose of the field test program was to characterize gaseous emissions from a wood preserving facility using a cooling tower identified as plant C. The cooling tower was used to reduce wastewater volume generated by the treating process. Field sampling was conducted during the period May 21, 1979 to May 25, 1979. Mr. Bruce C. DaRos served as the field project engineer and was assisted by Messrs. Peter Kaufmann and Charles Black.

The wood preserving facility selected for field sampling employed the Boulton drying process to effect treatment. Figures B-1 and B-2 present photographs (front and rear views, respectively) of the retort (8-foot diameter x 144 feet). The treating process can use either penta- or creosote-based preservatives. During this field test program, the plant was using 5 percent penta dissolved in medium-weight aromatic treating oil. Two charges of Douglas fir utility poles were treated during the field tests. Tables B-1 and B-2 present the process matrix and charge characteristics. Wastewater generated by the treating process is channeled to an oil/water separator as shown in Figure B-3. The penta/oil fraction, which floats to the surface, is returned to the bulk storage tank and the wastewater (actually an oil/water emulsion) is routed to the cooling tower for volume reduction and ultimate concentration of wastes into a sludge. However, the bulk of the sludge comes from settled solids in the oil-water separator, which is removed about every six months. As yet, the sludge from the cooling tower has not been removed, but it is to be collected with the other sludge, when needed. These sludges are pumped into a tank truck and discharged at an approved land fill.

A Fluor, Model 12C, Series 3 (single-cell, counterflow) cooling tower was used to reduce wastewater discharge and to supply cooling water to miscellaneous process functions. Figure B-4 presents a photograph of the unit. Figure B-5 presents a schematic of the piping detail and tower geometry.

B.2 FIELD SAMPLE COLLECTION

Field sampling at the site consisted of:

- Determination of preliminary gas stream characteristics

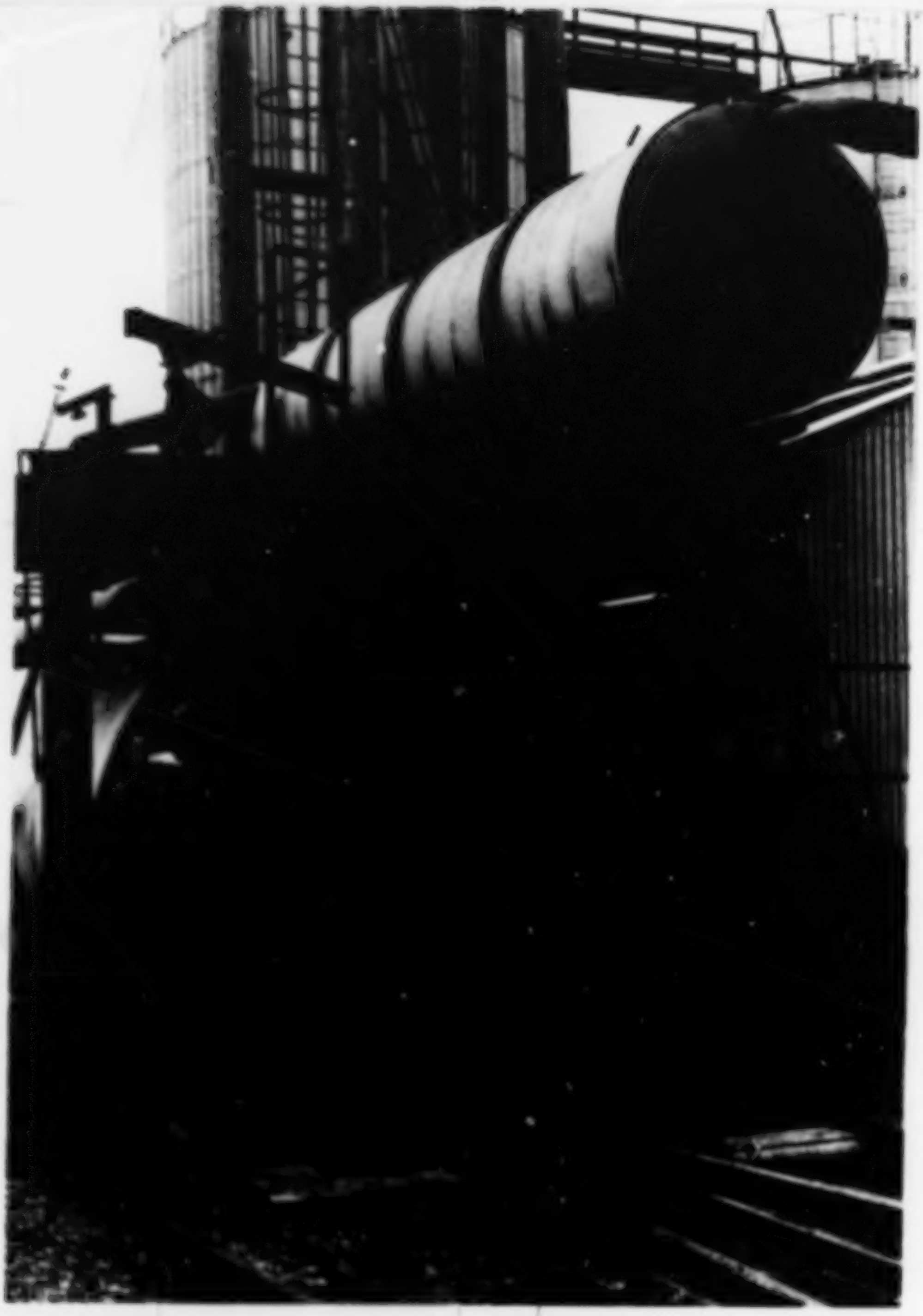


Figure B-1. Lower vessel -- front view of retort; upper vessel -- vacuum vessel.

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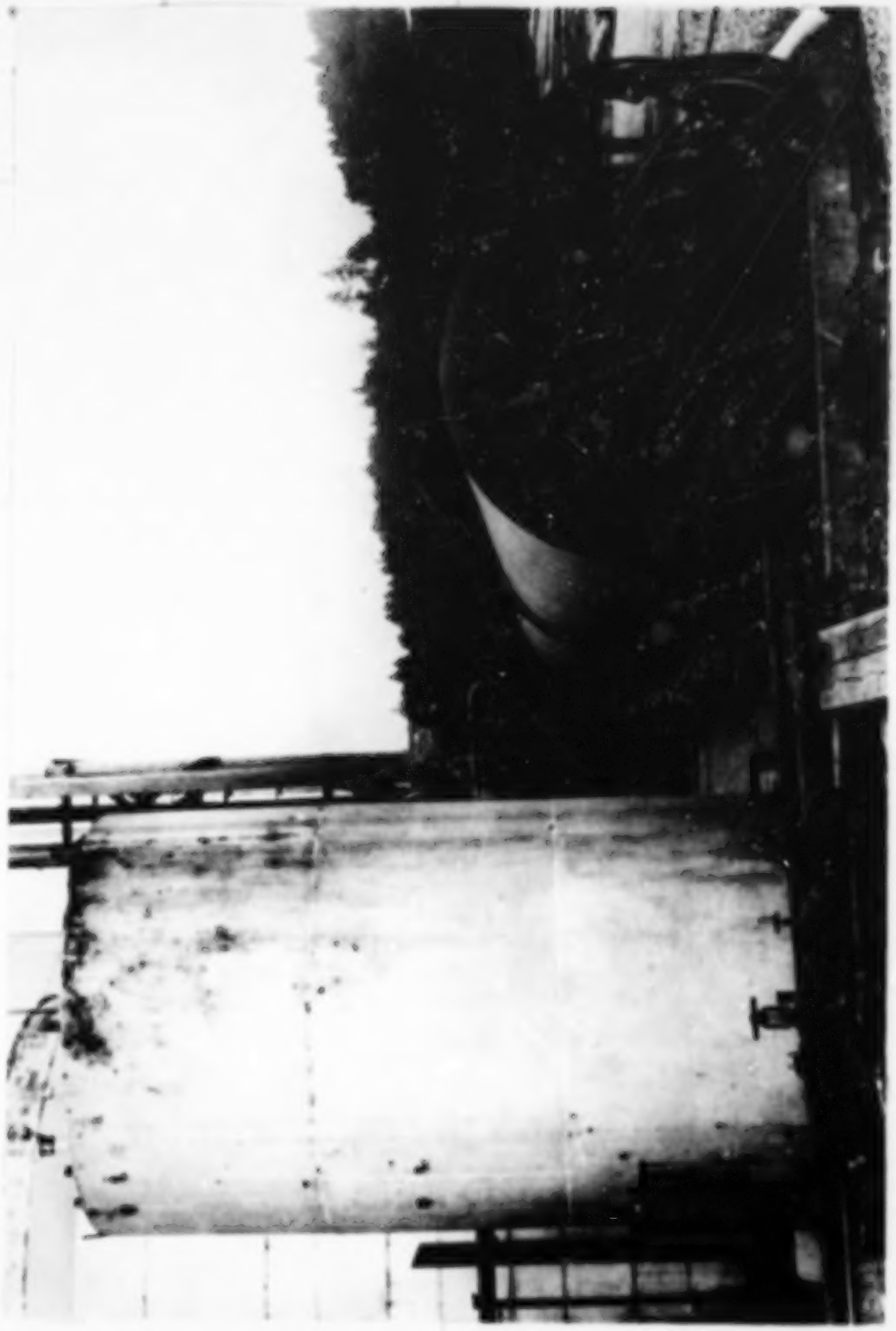

Figure B-2. Left vessel -- rear view of retort; right vessel -- preservative work tank.

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TABLE B-1. CHARGE I -- PROCESS MATRIX AND CHARGE CHARACTERISTICS

Date In:	May 21, 1979
Time In:	1100
Product Type:	Douglas Fir Utility Poles
Condition:	Wet
Size:	Medium[a] -- 70.55 m^3[b]
Preservative Type:	Penta-A (penta in aromatic oil)

Record of Operation

Activity	Maximum temperature (°F)	(°C)	Maximum pressure (psi)	Vacuum (in. Hg)	Clock time	Duration (hr:min)
Change charge					1100	00:30
Steam condition						
Vacuum				5	1130	00:15
Oil condition	220	104.4		23	1145	27:45
Air pressure			15		1530	00:30
Pressure period	190	87.8	110		1600	
Expansion bath	210	98.9		23.5	1715	2:30
Vacuum					1945	00:30
Steam	240	115.6			2015	3:00
Vacuum					2315	1:00
						37:15[c]

---

[a] Medium size utility poles

[b] Estimated volume of timber being treated

[c] Treatment time based on total change in humidity

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TABLE B-2. CHARGE II -- PROCESS MATRIX AND CHARGE CHARACTERISTICS

Date In:	May 23, 1979
Time In:	0030
Product Type:	Douglas Fir Utility Poles
Condition:	S-Wet
Size:	Large[a] -- 72.33 m^3[b]
Preservative Type:	Penta-A

Record of Operation

Activity	Maximum temperature (°F)	Maximum temperature (°C)	Maximum pressure (psi)	Vacuum (in. Hg)	Clock time	Duration (hr:min)
Change charge					0030	00:30
Steam condition						
Vacuum				5.5	0100	00:15
Oil condition	220	104.4		23	0115	28:45
Air pressure			15		0600	00:30
Pressure period	185	85	110		0630	2:00
Expansion bath	210	98.9		23.5	0830	5:00
Vacuum					1100	00:30
Steam	240	115.6			1400	3:00
Vacuum					1700	1:00
						41:30

NOTE: 2 hours and 30 minutes extra time on expansion bath -- boiler was down for repair

[a] Large size utility poles
[b] Estimated volume of timber treated

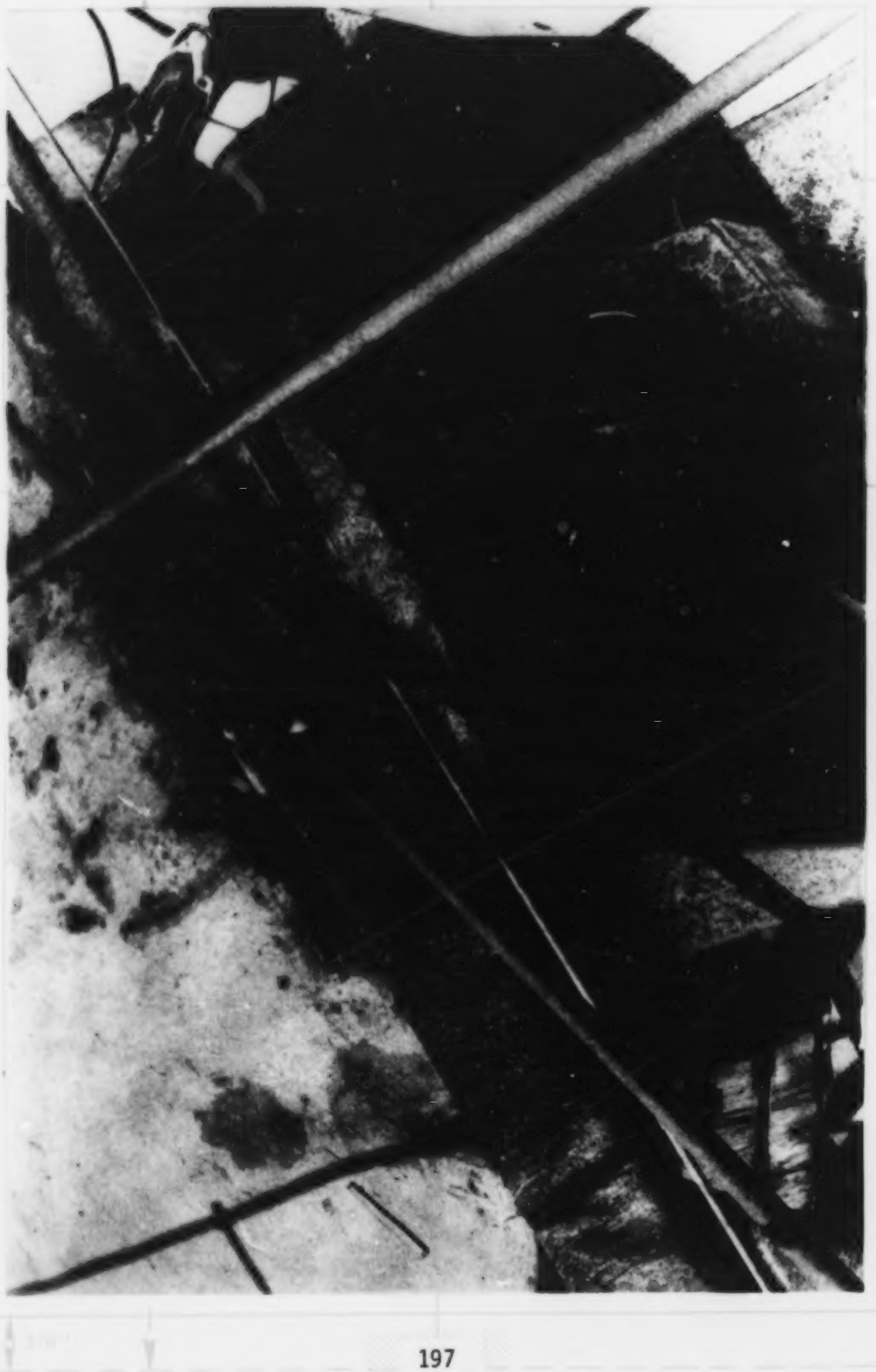

Figure B-3. Top view of secondary oil/water separator.

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(PREVIOUSLY ETN. EPA FORM 341)

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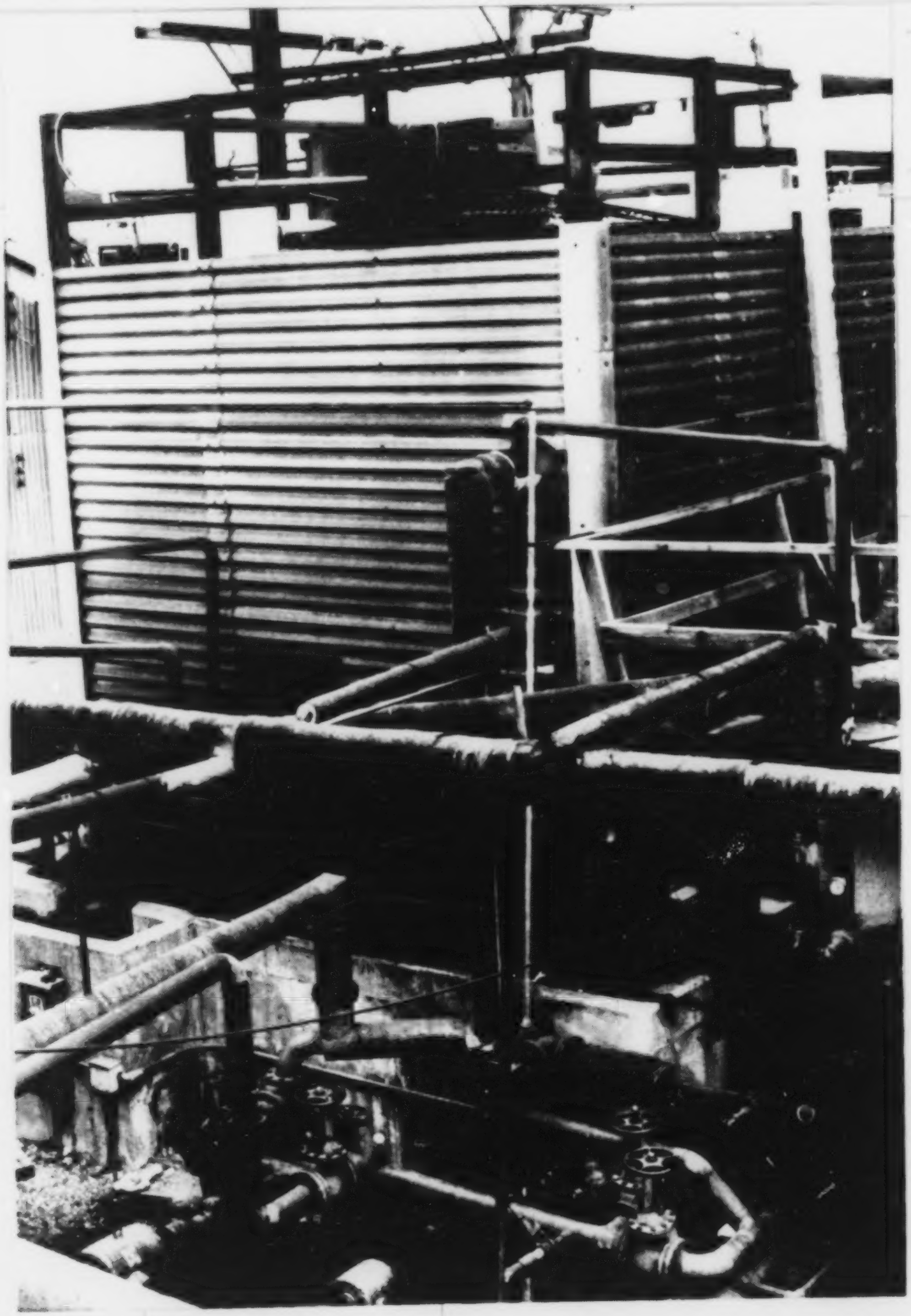

Figure B-4. Cooling tower.

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BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

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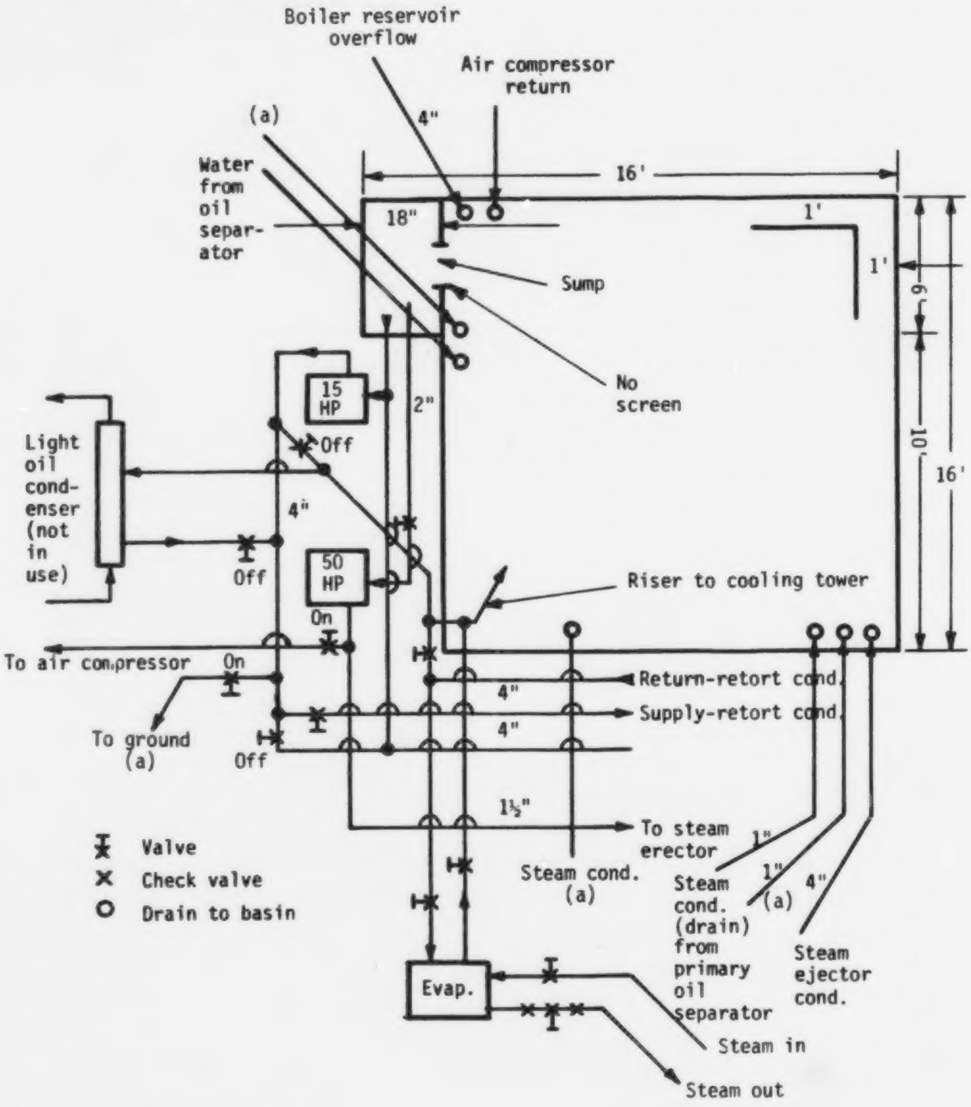
EPA Form 2320-4 (4-80)
(PREVIOUSLY EPA FORM 231)
TYPING GUIDE SHEET



Boiler reservoir overflow
Air compressor return
(a)
4"
Water from oil separ- ator
16'
18"
1'
1'
Sump
9'
No screen
15 HP
2"
Off
Light oil cond- enser (not in use)
10'
16'
4"
Off
50 HP
Riser to cooling tower
On
To air compressor
On
Return-retort cond.
4"
Supply-retort cond.
To ground (a)
4"
Off
1½"
To steam erector
1"
Valve
Check valve
Drain to basin
Steam cond. (a)
Steam cond. (drain) from primary oil separator
1"
(a)
4"
Steam ejector cond.
Evap.
Steam in
Steam out

---

[a] Purpose or source for these lines is unknown. No wastewater was flowing in these lines during the test period.

Figure B-5. Piping diagram of a cooling tower.

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- Isokinetic source sampling (sampling at a rate equivalent to the stack gas velocity)
- Liquid process stream sampling
- Collection of plant operating/production data for the sampling period

Table B-3 presents the field test matrix used during the test program.

Preliminary gas characteristics were determined using Federal Register (Vol. 42, No. 160, August 18, 1977) Methods 1 through 4. Preliminary measurements were performed 6 inches above the cooling tower fan enclosure with the unit operating under normal load conditions. Exit gas velocity pressure measurements were obtained using a calibrated 6-foot S-type pitot tube in conjunction with a 0- to 1-inch Magnehelic Series 200 gauge manufactured by Dwyer Instruments Company, Michigan City, Indiana. Exit gas temperatures were measured using a Chromel-Alumel (Type K) thermocouple and a digital thermal indicator manufactured by Doric Incorporated. Table B-4 presents a summary of the velocity/temperature profile data. Figure B-6 presents a schematic of the traverse point locations. Preliminary gas moisture content was calculated using psychrometric data. Successive moisture values, as determined by EPA Method 5 data obtained during actual sampling runs, were then used to update the preliminary values. Because of the low concentration of organic materials, the exit gas molecular weight was assumed to be that of air.

Samples of high-molecular-weight airborne emissions from the cooling tower were collected using a modified EPA Method 5 isokinetic sampling train. The modified train consisted of a heated, glass-lined probe, an XAD-2 polymer sorbent trap, one modified Greenburg-Smith impinger filled with 100 ml of distilled water, and a silicon dioxide dryer trap to protect the pump and sampling module from moisture. Figure B-7 presents a schematic of the sampling system. Figure B-8 presents a photograph of the train in sampling position. The sample control modules monitor sampling parameters such as gas volume sampled, gas temperature, and elapsed time.

For each isokinetic source test, a sample was drawn from the fan outlet at a predetermined constant velocity point through a probe fitted with the appropriately sized nozzle. Three complete sets of samples were collected. One train was operated continuously for a total of 8 hours. A second train was operated for 4 hours, followed by XAD-2 cartridge change, then continuation of sampling with fresh XAD-2 in conjunction with the 8-hour train. During turnaround for the 4-hour sampling trains, the 8-hour train was stopped and then restarted to maintain equal time frames. Table B-5 presents a summary of the source sampling time schedule for testing. Figure B-9 presents an aerial view of the modified EPA Method 5 sampling trains in sampling position.

At the completion of source sampling, the sample train and probes were transported to a field laboratory. Samples were analytically transferred from the sample trains to specially cleaned and labeled storage containers. The

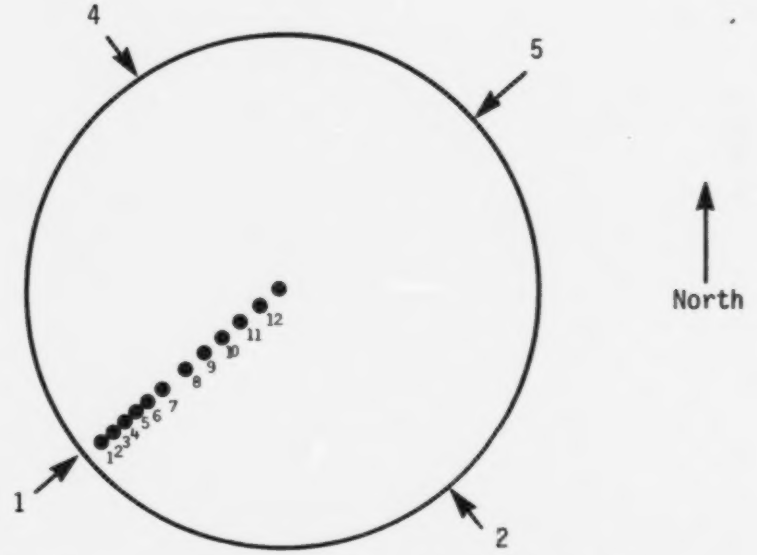
TABLE B-3. FIELD SAMPLING MATRIX -- NUMBER OF SAMPLES COLLECTED/DAY

Sampling location	Source sampling (modified EPA Method 5)		Liquid composite samples collected at 0.5-hour intervals
	4-hour test	8-hour test	
Cooling tower exhaust fan	2	1	
Process feed (from secondary oil/water separator			1 (Approx. 2 gallons)
Reflux (cooling tower circulating water)			1 (Approx. 2 gallons)
Basin reservoir			1 (Approx. 2 gallons)
Basin sludge			1 (Approx. 2 gallons)

TABLE B-4. SUMMARY OF THE VELOCITY/TEMPERATURE PROFILE DATA

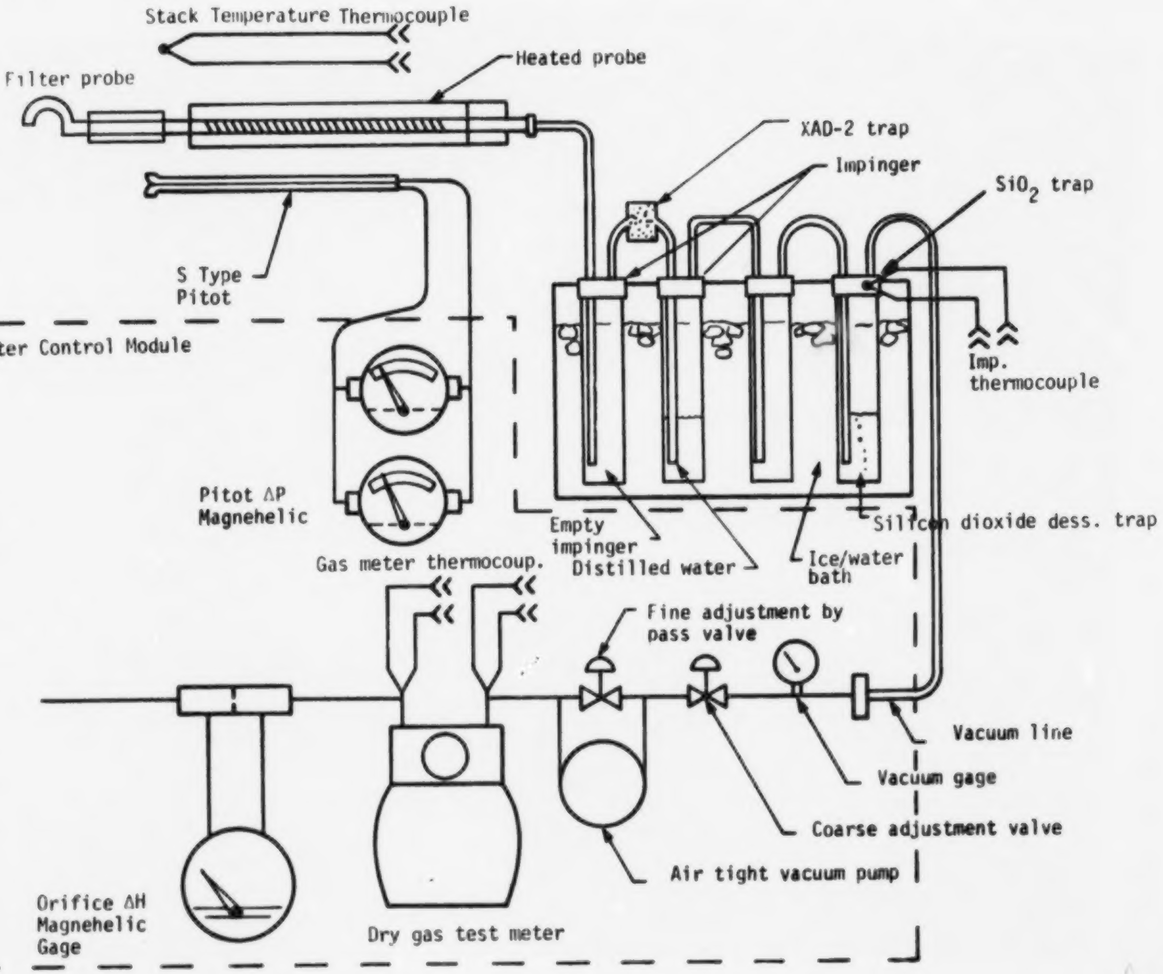
Location no.	Station 1		Station 2		Station 3		Station 4	
	ΔP in. H_2O	Temp. °F	ΔP in. H_2O	Temp. °F	ΔP in. H_2O	Temp. °F	ΔP in. H_2O	Temp. °F
1	0.055	73	0.15	69	0.05	70	0.03	72
2	0.11	74	0.21	70	0.09	72	0.03	74
3	0.165	72	0.26	69	0.15	73	0.07	73
4	0.26	71	0.38	68	0.36	72	0.11	73
5	0.31	70	0.38	68	0.33	71	0.23	72
6	0.325	69	0.38	67	0.32	70	0.32	72
7	0.35	68	0.33	67	0.28	69	0.41	70
8	0.35	68	0.40	67	0.26	68	0.40	69
9	0.29	68	0.42	67	0.23	68	0.36	68
10	0.11	67	0.25	67	0.20	67	0.26	68
11	0.14	68	0.13	67	0.16	67	0.10	68
12	0.02	68	-0.02	68	0.02	67	0.00	68

Fan housing I.D. = 97-1/2 inches (24 points per diameter)


4
5
North
1
2
1
2
3
4
5
6
7
8
9
10
11
12

Point No. (Stations 1, 2, 3 and 4)	Location from inside fan housing shroud, inches
1	1-1/16
2	3-1/16
3	5-3/8
4	7-11/16
5	10-1/4
6	12-7/8
7	15-11/16
8	18-15/16
9	22-3/8
10	26-1/2
11	31-1/2
12	38-13/16

Figure B-6. Schematic of traverse point locations.



Stack Temperature Thermocouple
Heated probe
Filter probe
XAD-2 trap
Impinger
SiO_2 trap
S Type Pitot
Meter Control Module
Imp. thermocouple
Pitot ΔP Magnehelic
Empty impinger
Silicon dioxide dess. trap
Gas meter thermocoup.
Distilled water
Ice/water bath
Fine adjustment by pass valve
Vacuum line
Vacuum gage
Coarse adjustment valve
Air tight vacuum pump
Orifice ΔH Magnehelic Gage
Dry gas test meter

Figure B-7. Schematic of modified EPA Method 5 isokinetic source sampling system.

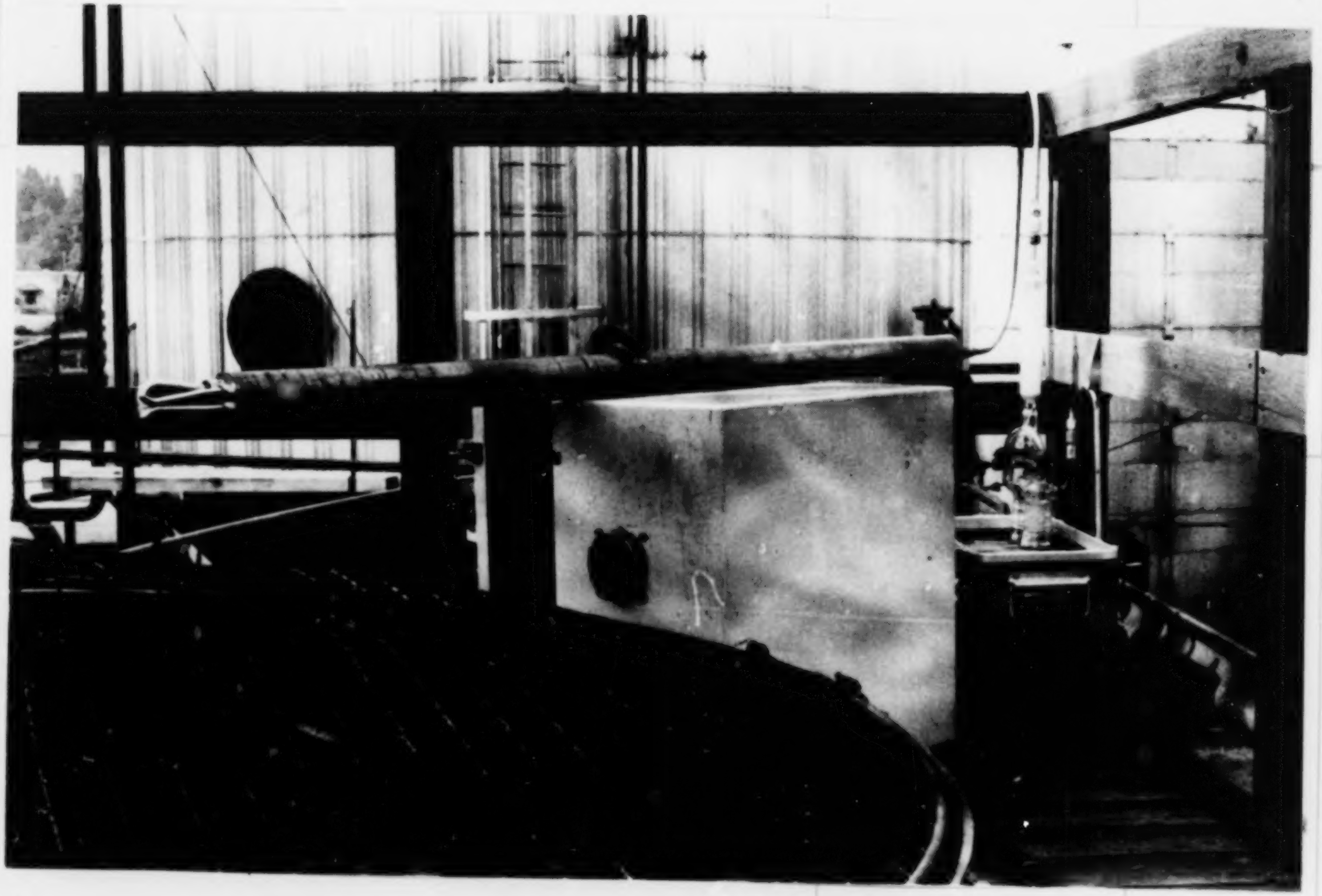


Figure B-8. Modified EPA Method 5 sampling train.

TABLE B-5. SUMMARY OF THE SOURCE SAMPLING TIME SCHEDULE -- COOLING TOWER FAN OUTLET

Test no.	Date	Clock time start	Clock time stop	Duration hours
1-4 hr.-A	5-22-79	0923	1323	4
1-8 hr.	5-22-79	0923 1430	1323 1830	8
1-4 hr.-B	5-22-79	1430	1830	4
2-4 hr.-A	5-23-79	0812	1212	4
2-8 hr.	5-23-79	0812 1240	1212 1640	8
2-4 hr.-B	5-23-79	1240	1640	4
3-4 hr.-A	5-24-79	0800	1200	4
3-8 hr.	5-24-79	0800 1215	1200 1615	8
3-4 hr.-B	5-24-79	1215	1615	4

NOTE: Two 4-hour tests were conducted concurrently with the one 8-hour test to protect against breakthrough of organic compounds through the XAD-2.

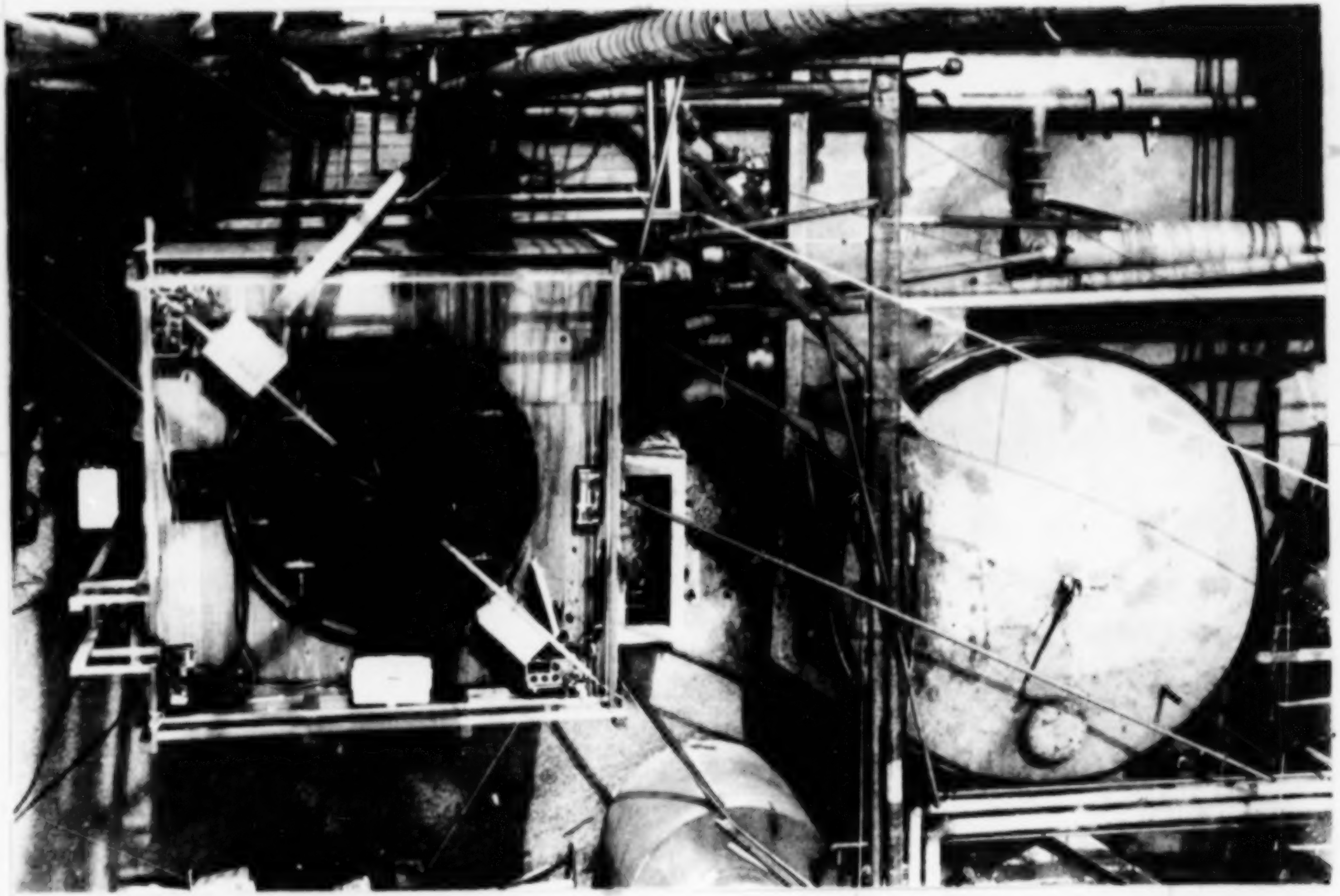


Figure B-9. Modified EPA Method 5 sampling train in sampling position.

probe nozzle, probe, and connecting lines were also analytically cleaned and the recovered samples transferred to appropriate storage containers. Immediately following sample recovery, all samples were iced in the field and maintained under those conditions for their transport to the Mountain View laboratory.

Table B-6 presents the sampling parameters. All but one test were isokinetic. The nonisokinetic test was caused by a higher than usual pressure drop across the sampling train. This was probably due to moisture accumulation in the XAD-2 cartridge. The raw (sample train operation) data is presented in an addendum following this appendix.

Liquid samples of the process stream, cooling tower reflux and sludge were collected during the 3-day sampling period. Table B-3 presented the sample matrix used during liquid sample collection.

For each sample location, 2-gallon manual composites were collected daily. Liquid sample collection was initiated to coincide with the start of source testing. Compositing was effected by collecting approximately 500-ml aliquots at 0.5-hour intervals at each sampling location. After collection, all samples were immediately iced and maintained on ice for transportation to the Mountain View laboratory.

B.3 ANALYTICAL METHODS

The samples collected during field testing of the cooling tower at Plant C were extracted and analyzed as described in Appendix A.4. Water samples, sludge samples, and XAD-2 cartridges were extracted and analyzed for acidic organics by gas chromatography. TCDD and OCDD were determined by Wright State University, an Acurex subcontractor for dioxin analysis, using GC/MS.

B.4 TEST RESULTS

An acid extract from the Day 1 feed sample was analyzed by GC/MS. Figure B-10 shows the total ion current chromatogram for this analysis. Penta was the dominant species. Others that could be identified but not necessarily quantified are: tetrachlorophenol (isomer unknown), benzoic acid, toluic acid (isomer unknown), trichlorophenol (isomer unknown), and phenol.

GC/MS analysis of an extract of the sludge sample collected from the cooling tower indicated that penta constituted almost 3 percent of the sludge as shown in Table B-9. Other species identified in the sludge were benzoic and toluic acids, trichlorophenol, and PAH's, including naphthalene and phenanthrene. The plant had terminated the use of creosote over 4 years prior to this test program.

Table B-7 lists the results for dioxin analysis of samples from Test Day 2. No TCDD was detectable in any of the samples. OCDD was present in the feed water, reflux water, and concentrated in the sludge. Results for classical analyses on samples from Test Day 2 are presented in Table B-8.

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TABLE B-6. SUMMARY OF MODIFIED EPA METHOD 5 SAMPLING PARAMETERS AND PERCENT ISOKINETICS

Test no.	Location traverse point no.	Molecular weight (dry) lb/lb-mole	Avg. stack temp. °F	Avg. stack temp. °C	Barometric pressure in. Hg	Static pressure in. H_2O	Volume dry gas sampled at STP scf	DNM3/Dry normal cubic meters	Moisture content % H_2O	Exit gas velocity at stack condition ft/sec	M/sec meters per second	Exit gas volume at STP scfm	NM^3 normal cubic meters	Test Percent isokinetic
1-4 hr-A	2-10	28.84	64	17.8	30.25	-0.03	213.969	6.06	14	30.6	9.33	95,473	2,703.8	94.2
1-8 hr	4-10	28.84	72	22.2	30.25	-0.03	512.401	14.51	15	26.1	7.96	80,212	2,271.6	93.0
1-4 hr-B	2-10	28.84	65	18.3	30.25	-0.03	189.768	5.37	20	27.5	8.38	81,308	2,302.6	93.6
2-4 hr-A	2-10	28.84	65	18.3	30.05	-0.03	205.279	5.81	20	29.2	8.90	89,917	2,546.4	96.2
2-8 hr-B	4-10	28.84	74	23.3	30.05	-0.03	466.483	13.21	10	26.8	8.17	81,380	2,304.7	
2-4 hr-B	2-10	28.84	67	19.4	30.05	-0.03	211.208	5.98	20	29.8	9.08	91,399	2,588.4	97.3
3-4 hr-A	2-10	28.84	61	16.1	30.22	-0.03	206.688	5.85	10	30.0	9.14	90,739	2,569.7	95.9
3-8 hr	4-10	28.84	74	23.3	30.22	-0.03	508.099	14.39	11	25.6	7.80	78,435	2,221.3	94.2
3-4 hr-B	2-10	28.84	66	18.9	30.22	-0.03	209.359	5.93	10	29.6	8.12	91,698	2,596.9	96.0
												86,729	2,456.2	
Average		28.84				-0.03								

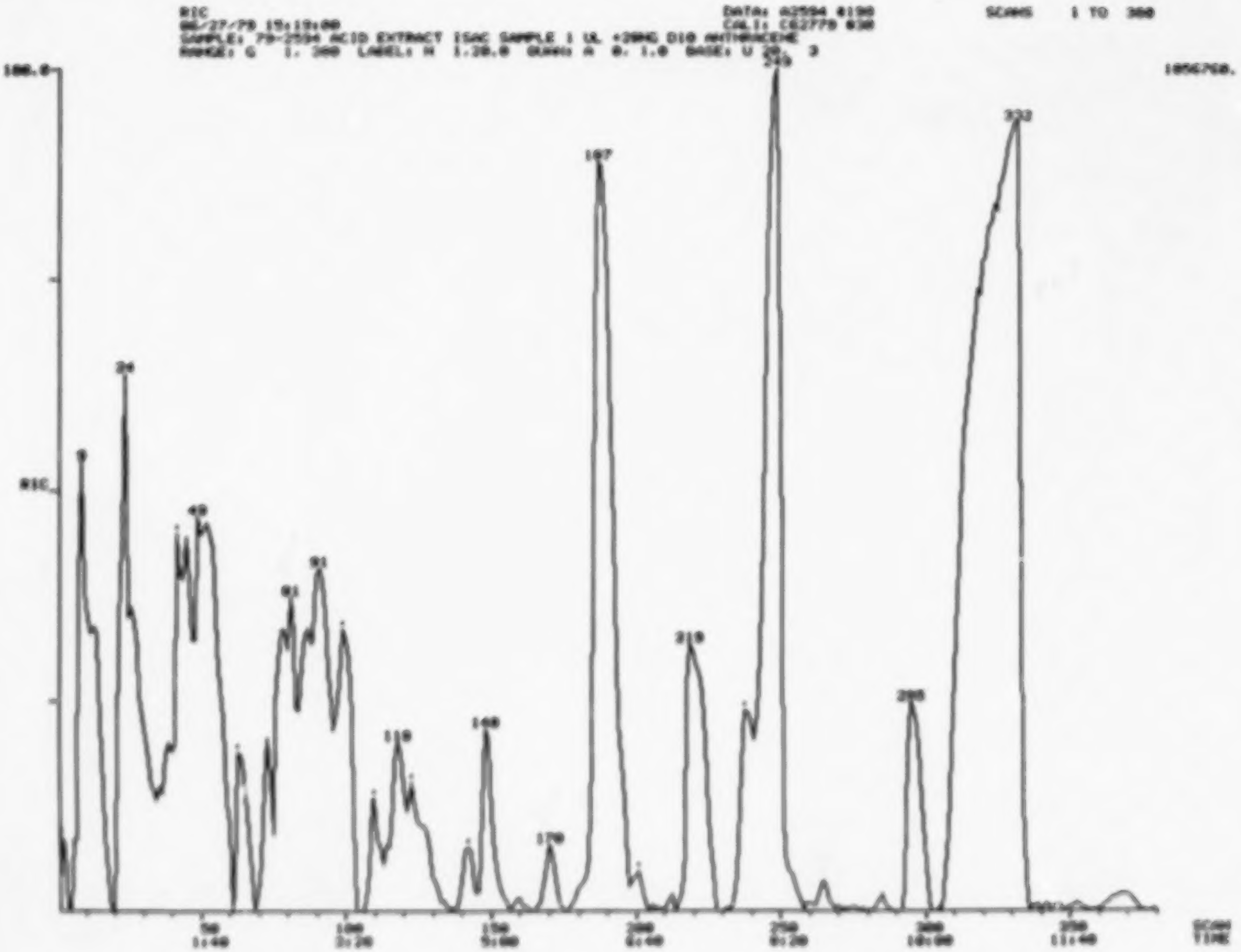

Figure 8-10. Total ion current chromatogram.

TABLE B-7. DIOXIN CONTENT OF COOLING TOWER SAMPLES

Sample	Detection limits TCDD (parts per trillion)	OCDD (parts per billion)
Feed	>100	34
Reflux	>100	27
Sludge	>8000	16,000

NOTE: Samples from Day 2 arbitrarily selected for analysis.

TABLE B-8. CLASSICAL PARAMETER ANALYSIS OF COOLING TOWER SAMPLES (mg/l)

Sample	Feed water	Reflux water	Sludge
Phenols	0.7	3.2	6.2
Oil and Grease	720	600	58,000
Chemical Oxygen Demand	8,500	9,400	254,000
Total Suspended Solids	160	110	--
Total Dissolved Solids	6,700	6,900	--
Total Solids (103°C)	--	--	27 percent

NOTE: Samples from Day 2 arbitrarily selected for analysis

TABLE B-9. ANALYTICAL RESULTS

		Description			Concentration[a]		
ID no.	Sample				Penta	Tetrachlorophenol	Phenol
79-2591	Bottoms	0-4 hrs	Test Day 1	5/22/79	1200	110	1
79-2593	Corners		Test Day 1	5/22/79	1000	95	1
79-2594	Feed 1	0-4 hrs	Test Day 1	5/22/79	810	75	1
2595	Feed 1	4-8 hrs	Test Day 1	5/22/79	1000	130	1
2596	Reflux	0-4 hrs	Test Day 1	5/22/79	1100	90	1
2597	Reflux	4-8 hrs	Test Day 1	5/22/79	1300	120	1
2598	Sludge	0-4 hrs	Test Day 1	5/22/79	28	0.8	0.1
2600	4HA-XAD-2	0-4 hrs	Test Day 1	5/22/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0042
2601	4H-XAD-2	4-8 hrs	Test Day 1	5/22/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0038
2602	8H-XAD-2	0-8 hrs	Test Day 1	5/22/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0054
2603	XAD-2	Blank			$<5x10^{-5}$	$<5x10^{-5}$	$<5x10^{-5}$
2616	Silica Gel	Blank			$<5x10^{-5}$	$<5x10^{-5}$	$<5x10^{-5}$
2620	8H Silica Gel	0-4 hrs	Elapsed	5/22/79	$<5x10^{-5}$	$<5x10^{-5}$	$<5x10^{-5}$
2626	Feed 1	0-4 hrs	Test Day 2	5/23/79	790	65	1
2627	Feed 1	4-8 hrs	Test Day 2	5/23/79	1000	80	1
2628	Reflux	0-4 hrs	Test Day 2	5/23/79	1400	160	1
2629	Reflux	4-8 hrs	Test Day 2	5/23/79	1000	90	1
2632	4HA-XAD-2	0-4 hrs	Test Day 2	5/23/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0029
2633	4HB-XAD-2	4-8 hrs	Test Day 2	5/23/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0035
2634	8H-XAD-2	0-8 hrs	Test Day 2	5/23/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0028
2658	Feed 1	0-4 hrs	Test Day 3	5/24/79	1000	80	1
2659	Feed 1	4-8 hrs	Test Day 3	5/24/79	780	85	1
2660	Reflux	0-4 hrs	Test Day 3	5/24/79	1200	110	1
2661	Reflux	4-8 hrs	Test Day 3	5/24/79	630	65	1
2664	4HA-XAD-2	0-4 hrs	Test Day 3	5/24/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0026
2665	4HB-XAD-2	4-8 hrs	Test Day 3	5/24/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0028
2666	8H-XAD-2	0-8 hrs	Test Day 3	5/24/79	$<5x10^{-5}$	$<5x10^{-5}$	0.0027

[a] Units of Concentration for: XAD-2 Cartridges -- mg/m^3
Sludge -- mg/g (wet weight)
Waters -- mg/l

Analytical results for the determination of penta, tetrachlorophenol, and phenol in all samples are presented in Table B-9. The results indicate consistent feed levels during the 3 days of testing. Similar levels of penta and TCP were seen in the various samples taken inside the tower (bottoms, corner, and reflux). No evidence was found for penta or tetrachlorophenol emissions in the XAD-2 traps under the conditions existing at the time of the test. Phenol was present in all XAD-2 samples.

B.5 CALCULATION OF MASS EMISSION AND CONCLUSION

Using the EPA Method 2 velocity profile data and the following equations, the total exit gas volume from the cooling tower can be calculated. EPA Method 2 Data:

Stack area = 51.85 ft^2 (97.5-inch diameter)

Average ΔP of velocity pressure = 0.435 inch of H_2O

Average stack temperature = 69°F

Calculate exit gas velocity:

$$V_s = 85.49\ (Cp)\ (\sqrt{\Delta P}\ )_{avg}\ \sqrt{\frac{T_{s\ avg} + 460}{P_s\ MW_s}}$$

where V_s = exit gas velocity, ft/sec.

V_{sm} = exit gas velocity, meters/sec. = $V_s \cdot 0.3048$

85.49 = pitot tube constant, dimensionless

C_p = pitot tube coefficient, dimensionless

ΔP_{avg} = velocity pressure in H_2O

T_s = exit gas temperature, ^oF

P_s = stack pressure, in. Hg

MW_s = exit gas molecular weight wet, lb/lb-mole

$$V_s = 85.49\ (0.78)(0.435)\ \sqrt{\frac{69 + 460}{(30.25)(28.65)}}$$

$$= 22.7 \text{ ft/sec}$$

$$V_{sm} = 22.7 \cdot 0.3048$$

$$= 6.91 \text{ m/sec}$$

Calculate exit gas volume at standard temperature and pressure (STP):

$$Q_s = 60 \left(1-B_{wo}\right)\left(V_{s\ avg}\right)\left(A_s\right)\left(\frac{528}{T_s + 460}\right)\left(\frac{P_s}{29.92}\right)$$

$$Q_{sm} = Q_s \cdot 0.0283$$

where Q_s = exit gas volume at standard conditions, scfm

Q_{sm} = exit gas volume at standard conditions, NM^3/M

60 = sec/min

B_{wo} = water vapor in gas stream, proportion by volume

V_s = exit gas velocity, ft/sec

A_{savg} = average area of the stacks, ft^2

528 = standard temperature ^oK

T_s = exit gas temperature, ^oF

P_s = stack pressure, inches Hg

29.92 = standard pressure, inches Hg

$$Q_s = 60\ (1 - 0.17)(22.7)(51.85)\left(\frac{528}{69+460}\right)\left(\frac{30.25}{29.92}\right)$$

$$= 70{,}044 \text{ scfm at STP}$$

$$Q_{sm} = 70{,}044 \cdot 0.0283$$

$$= 1984.3\ NM^3/M \text{ at STP}$$

Relating the volumetric gas volume from the tower to the phenol emission rate data presented in Table B-9, the mass emission rate for phenols can be determined.

Using an average phenol concentration value of 0.0034 mg/m^3 for nine source emission tests (Table B-9), the phenol discharge rate is 6.7 mg/min.

Phenol concentration in the feedwater from the secondary oil/water separator is presented in Table B-9 to be <1 mg/l. For a measured flowrate of 17 gpm (63.8 l/min), the phenolic concentration entering the tower is calculated to be 0.11 mg/min.

Conclusions to be drawn from this effort include:

- A low molecular weight organic compound (phenol) was emitted from the tower
- As molecular weight increases, the probability of emissions to the ambient air decreases
- The tower mist eliminator controlled any drift (carryover) as evidenced by the absence of organic constituent concentrations similar to those in the reflux liquid

The cooling tower, operating under conditions similar to those of the test program, is an effective device for water evaporation while controlling organic emissions to the atmosphere.

Results and conclusions concerning the quality of this data is presented in the body of the report.

ADDENDUM

RAW FIELD DATA

ACUREX Corporation

8.340

PARTICULATE TEST FIELD DATA SHEET

Plant
Date 5/22/79
Test Location Cooling tower
Run Number 1 4hr A
Stack Diameter inches 97.5
Duct Dimensions in. x in.
Start Time 0923
Operator Kortmann

Barometric Pressure 30.25
Static Pressure -.03" H2O
Stack Pressure
Probe Number
Pitot Coefficient ~.78
Pitot Number
Meter Box Number 084
Orifice Coefficient .683

Nozzle Size & Number .307
Molecular Weight 28.84
BWO .014

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO2	O2	CO
-	23				
	63.3				
SILICA GEL					
200	40.3				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT3	TEMPERATURES °F							PUMP VACUUM in. Hg	√ΔP	
					STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT			initial leak check
2-10	0	.35	2.9	271.566	61		68			60	60	12	.59	.002/15"
	15	.35	2.9		62		65			63	62	13	.59	
	30	.35	2.9		62		66			65	63	14	.59	
	45	.35	2.9		62		67			66	64	14	.59	
	60	.35	2.9	323.35	63		68			67	65	13	.59	
	75	.35	2.9		63		69			68	66	13	.59	
	90	.35	3.0		62		68			69	67	14	.59	
	105	.35	3.0		63		69			70	68	14	.59	
	120	.35	3.0	376.17	62		68			72	69	14	.59	
	135	.36	3.0		65		69			72	70	14	.60	
	150	.35	2.9		67		66			73	70	14	.59	
	165	.35	2.9		67		67			75	71	14	.59	
	180	.35	2.9	429.59	67		68			73	71	14	.59	
	195	.35	3.0		66		67			75	72	14	.59	
	210	.36	3.1		66		67			78	73	.14	.60	
	225	.35	3.0		66		69			79	75	14	.59	
off	240			483.625										
AVG/TOTAL		.35	3.0	212.059	64					69			.59	

PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$213.969 = 17.64 \frac{212.059}{1.007} \left(\frac{30.25 + \frac{3.0}{13.6}}{69 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{63.3}{Vl_c}$$

2.980 =

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

.014 =

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

28.84 =

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$$

28.688 =

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

30.248 =

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$

$$30.572 = 85.49(.78)(.59)\sqrt{\frac{64+460}{(30.248)(28.688)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\left(1 - B_{wo}\right) Vs_{avg}\ A_s \left(\frac{528}{T_s\ avg + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$95473 = 60\underset{.986}{(1-.014)}\ 30.572\ \underset{57.45}{(\cancel{24662})}\underset{1.007}{\left(\frac{528}{64+460}\right)}\underset{1.011}{\left(\frac{30.25}{29.92}\right)}$$

9. Test percent isokinetic

$$\%I = \frac{17.33\ \left(T_s + 460\right)\left[0.04707\ \left(V1_c\right) + Vm_{std}\right]}{\theta\quad V_s\quad P_s\quad D_n^2}$$

$$94.2 = \frac{17.33(524)(2.98 + 213.969)}{240(30.572)(30.248)(.307)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432\ \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857\ (Q_s)\ C_s$$

=

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\left[\%O_2 - 0.5\ (\%CO)\right]}{0.264\ \left[\%N_2 - (\%O_2 - 0.5 \times \%CO)\right]}$$

=

$$A_s = \pi\left(\frac{1D}{2}\right)^2$$

$$\pi\left(\frac{97.5}{2}\right)^2 = 7466.2 \qquad \overset{57.848}{\cancel{12.76\ ft^2}}$$

ACUREX Corporation - 15.576

PARTICULATE TEST FIELD DATA SHEET

Plant
Date May 22, 79
Test Location Cooling Tower
Run Number 1 Bay
Stack Diameter inches 97.5
Duct Dimensions in. x in.
Start Time 0925
Operator B.C. DaRos

Barometric Pressure 30.25
Static Pressure -.03" H_2O
Stack Pressure
Probe Number
Pitot Coefficient .78
Pitot Number
Meter Box Number 0015
Orifice Coefficient .722

Nozzle Size & Number .369
Molecular Weight 28.84
BWO .015

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO_2	O_2	CO
-	50				
	170.8				
SILICA GEL ~~200~~	20.8 43.3				
200	59.7				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in. Hg	$\sqrt{\Delta P}$	
														initial leak
4-10	0	.25	3.9	704.52	69		68			68	68	7	.50	.002/15"
	15	.25	3.9		69		65			72	68	7	.50	
	30	.24	3.8		69		66			76	69	7	.49	
	45	.24	3.8		68		67			77	71	7	.49	
	60	.25	3.9	767.63	70		68			78	72	7	.50	
	75	.24	3.8		70		69			79	72	7	.49	
	90	.24	3.8		69		68			79	73	7	.49	
	105	.24	3.8		72		69			79	74	7	.49	
	120	.25	3.9	830.90	71		68			80	75	7	.50	
	135	.25	4.0		70		69			81	75	7	.50	
	150	.24	3.8		70		66			82	75	7	.49	
	165	.24	3.9		74		67			81	76	7	.49	
	180	.24	3.8	894.72	75		66			83	77	7	.49	
	195	.25	3.9		75		67			81	77	7	.50	
	210	.26	4.1		74		67			83	78	7	.51	
	225	.26	4.1		74		69			84	78	7	.51	
off	240	~~.26~~		959.254										.002/15"
on 1344	240	.26	4.1	959.438	75		77			78	78	6	~~.24~~	
	255	~~.26~~	4.1	975.421	74		72			81	77	6	~~.24~~	
	270	~~.26~~												
AVG/TOTAL														

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PARTICULATE TEST FIELD DATA SHEET 1/2

Plant
Date 5-22-79
Test Location
Run Number
Stack Diameter inches
Duct Dimensions in. x in.
Start Time
Operator KAUFMANN

Barometric Pressure 30.25
Static Pressure
Stack Pressure
Probe Number
Pitot Coefficient
Pitot Number
Meter Box Number
Orifice Coefficient

Nozzle Size & Number
Molecular Weight
BWO

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO2	O2	CO
SILICA GEL					

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in. Hg	√ΔP	
4-10	285													
	300	.26	4.1	23.88	74		69			83	78	6	.51	
	315	.26	4.1	40.00	72		70			83	78	6	.51	
	330	.26	4.1		73		70			85	79	6	.51	
	345	.26	4.1		72		73			85	79	6	.51	
	360	.25	4.0		71		70			87	80	6	.50	
	375	.25	4.0		71		69			87	81	6	.50	
	390	.25	4.0		71		69			87	81	6	.50	
	405	.26	4.2		71		73			88	82	6	.51	
clock 1248	420	.26	4.1		71		75			84	82	6	.51	
	435	.25	4.0		73		77			88	82	14	.50	
	450	.26	4.1		73		79			88	83	14	.51	
	465	.25	4.0		75		78			88	83	14	.50	
off	480			270.188										
AVG/TOTAL			4.0	515.668	72					79			.50	

Form EED 021 1-79

5/23/79

PARTICULATE CALCULATIONS

Test 1 8hr.

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$512.401 = 17.64 \frac{515.668}{1.006} \left(\frac{30.25 + \frac{40}{13.6}}{79 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{170.8}{Vl_c}$$

8.040 =

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

.015 =

4. Stack gas dry molecular weight (lb/lb-mole)

$$Md_d = 0.44 (\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2 + \%CO)$$

28.84 =

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d (1 - B_{wo}) + 18 (B_{wo})$$

28.677 =

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

30.248 =

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$

$$26.111 = 85.49(.78)(.50)\sqrt{\frac{72 + 460}{(30.248)(\cancel{\text{[illegible]}})(28.677)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg}\ A_s \left(\frac{528}{T_{s\ avg} + 460}\right)\left(\frac{P_s}{29.92}\right)$$

$$80{,}212 = \underset{.985}{(1-.015)}\ 261\ (51.85)\underset{.992}{\left(\frac{528}{72 + 460}\right)}\underset{1.011}{\left(\frac{30.25}{29.92}\right)}$$

9. Test percent isokinetic

$$\%I = \frac{17.33\ \left(T_s + 460\right)\left[0.04707\ \left(Vl_c\right) + Vm_{std}\right]}{\theta\ V_s\ P_s\ D_n^2}$$

$$93.0 = \frac{17.33(532)(8.04 + 512.40)}{(480)(26.111)(30.248)(.369)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857\ (Q_s)\ C_s$$

=

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\left[\%O_2 - 0.5\ (\%CO)\right]}{0.264\left[\%N_2 - (\%O_2 - 0.5 \times \%CO)\right]}$$

=

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[illegible] Corporation

PARTICULATE TEST FIELD DATA SHEET

Plant
Date 5/22/79
Test Location Cooling tower
Run Number 1 4h B
Stack Diameter inches 2
Duct Dimensions in. x in. 97.5
Start Time 1430
Operator Wortmann

Barometric Pressure 30.25
Static Pressure -.03" H_2O
Stack Pressure
Probe Number
Pitot Coefficient ~.78
Pitot Number
Meter Box Number 04
Orifice Coefficient .683

Nozzle Size & Number .307
Molecular Weight 28.84
BWO .020

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO_2	O_2	CO
-	20				
	20.9				
SILICA GEL					
200	221.6				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. H_2O	ORIFICE METER ΔH in. H_2O	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in. Hg	$\sqrt{\Delta P}$	$005/10^8$
2-10	0	.28	2.4	483.625	68		77			74	74	12	.53	
	15	.28	2.4		66		72			73	73	10	.53	
	30	.28	2.4		66		72			73	72	10	.53	
	45	.28	2.4		65		72			72	72	10	.53	
	60	.28	2.4		65		71			72	71	10	.53	
	75	.28	2.4		65		70			73	72	10	.53	
	90	.28	2.4		65		70			73	72	10	.53	
	105	.28	2.4		65		73			74	72	10	.53	
	120	.28	2.4		65		70			74	73	10	.53	
	135	.28	2.4		64		69			76	74	10	.53	
	150	.28	2.4		64		69			76	74	10	.53	
	165	.28	2.4		65		73			77	75	10	.53	
	180	.28	2.4		64		75			77	76	11	.53	
	195	.28	2.4		64		77			78	76	11	.53	
	210	.28	2.4		64		78			78	76	11	.53	
	225	.28	2.4		65		76			78	76	11	.53	
[illegible]	240			673.752										
AVG/TOTAL		→	2.4	190.127	65					74			.53	

5/22/79
Test 1 4hB

PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$189.768 = 17.64 \frac{190.127}{1.007} \left(\frac{30.25 + \frac{2.4}{13.6}}{74 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{82.0}{Vl_c}$$

$$3.860 =$$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$$.020 =$$

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$28.84 =$$

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$$

$$28.623 =$$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$$30.248 =$$

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s \; MW_s}}$$

$$27.521 = 85.49(.78)(.53)\sqrt{\frac{65+460}{(30.248)(28.623)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg} \; A_s \left(\frac{528}{T_s \; avg + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$81{,}308 = \underset{.98}{(1-.020)} \; 27.5 \quad 51.85 \quad 1.005 \quad \underset{.964}{\left(\frac{28.84}{29.92}\right)}$$

9. Test percent isokinetic

$$\%I = \frac{17.33 \left(T_s + 460\right) \left[0.04707 \left(Vl_c\right) + Vm_{std}\right]}{\theta \quad V_s \quad P_s \quad D_n^2}$$

$$93.6 = \frac{17.33(525)(3.860 + 189.768)}{(240)(27.521)(30.248)(.307)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857 \left(Q_S\right) C_S$$

=

12. Percent excess air at sampling point

$$\% \; EA = \frac{100\left[\%O_2 - 0.5 \; (\%CO)\right]}{0.264 \left[\%N_2 - (\%O_2 - 0.5 \times \%CO)\right]}$$

=

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5-22-79

ISOKINETIC SAMPLING RATE CALCULATION

$$\Delta H = \left(\frac{60^2\ \pi^2 K_p{}^2 C_p{}^2 (1-B_{wo})^2 P_s M_d}{576^2 K_o{}^2 M_s P_m}\right) (N_d{}^4) \left(\frac{T_m}{T_s}\right) (\Delta P)$$

$$\Delta H = (K)\ (N_d{}^4) \left(\frac{T_m}{T_s}\right) (\Delta P)$$

$$K = \left(\frac{60^2\ \pi^2 K_p{}^2 C_p{}^2\ (1-B_{wo})^2\ P_s M_d}{576^2 K_o{}^2 M_s P_m}\right)$$

$$= \left(\frac{60^2\ \pi^2 85.49^2 C_p{}^2 (1-B_{wo})^2\ P_s M_d}{576^2 K_o{}^2 M_s P_m}\right)$$

$$= \left(\frac{782.687\ C_p{}^2 (1-B_{wo})^2 P_s M_d}{K_o{}^2 M_s P_m}\right)$$

Sta 2
$C_p = .78$
$K_o = .683$
$K = 938.835$
$K(Nd)^4 = 8.340$
$Nd = .307$

Sta 4
$C_p = .78$
$K_o = .722$
$K = 840.149$
$K(Nd)^4 = 15.3.76$
$Nd = .367$

8 1.007

$$\text{Sta 2} = \left(\frac{782.687\ (.78)^2 (1-.05)^2 (30.25)(28.85)}{(.683)^2 (28.31)(30.25)}\right)\ 938.835$$

8 1.006

$$\text{Sta 4} = \left(\frac{782.687\ (.78)^2\ (1-.05)^2\ (30.25)(28.85)}{(.722)(28.31)(30.25)}\right)\ 840.149$$

$$N_d = \left(\frac{\Delta H \qquad T_s}{K\ T_m \qquad \Delta P}\right)^{0.25}$$

$=$

use

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PARTICULATE TEST FIELD DATA SHEET 1/5

ACUREX Corporation

Plant

Date 5-23-79

Test Location Cooling Tower

Run Number 2 - 8hr.

Stack Diameter inches 97.5

Duct Dimensions in. x in

Start Time 0812

Operator Dykros/Kaufman

Barometric Pressure 30.05

Static Pressure -.03" H_2O

Stack Pressure

Probe Number

Pitot Coefficient ~.78

Pitot Number

Meter Box Number 0015

Orifice Coefficient .722

Nozzle Size & Number .369

Molecular Weight 28.84

BWO .1017

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES	
–	
	62
	166.4
SILICA GEL	
250	18.3
200	22.4
200	[illegible]
200	34.4

TIME	CO_2	O_2	CO

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in Hg	√ΔP	.004/16"
4-10	0812 000	.26	2.6/4.3	220.372	68		61			66	66	15	.51	
	15	.26	2.6/4.3		68		61			70	67	15	.51	not able to pull
	30	.26	2.6/4.3		69		60			75	70	15	.51	the correct ΔH
	45	.26	2.6/4.3		70		63			78	72	15	.51	
	60	.26	2.6/4.3	268.70	71		64			82	74	15	.51	
	75	.26	2.6/4.3		73		65			82	75	15	.51	
	90	.26	2.6/4.3		73		66			81	76	15	.51	
	105	.26	2.6/4.3		73		66			82	77	15	.51	
	120	.26	2.6/4.3	322.3	75		67			83	78	15	.51	
	135	.26	2.6/4.3		75		69			84	78	15	.51	
	150	.26	2.6/4.3		77		71			83	86	15	.51	
	165	.26	3.5/4.3		77		73			82	79	15	.51	
	180	.26	3.5/4.4	373.4	75		72			89	81	15	.51	
	195	.26	3.5/4.4		76		72			87	81	15	.51	
	210	.26	3.5/4.4		76		72			87	81	15	.51	
	225	.26	3.5/4.4		76		73			88	82	15	.51	
off	240			436.030										
	240	.26	3.9/4.3	436.030	77		70			80	80	5	.51	
	255	.26	3.5/4.3		77		70			82	80	15	.51	
	270	.26	3.5/4.3		76		70			84	81	15	.51	
AVG/TOTAL														

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PARTICULATE TEST FIELD DATA SHEET ⁷⁄₂

Plant :
Date 5/23/79
Test Location Cooling tower
Run Number 2 8hr.
Stack Diameter inches
Duct Dimensions in. x in
Start Time
Operator Devos

Barometric Pressure
Static Pressure
Stack Pressure
Probe Number
Pitot Coefficient
Pitot Number
Meter Box Number
Orifice Coefficient

Nozzle Size & Number
Molecular Weight
BWO

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO2	O2	CO
SILICA GEL					

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in Hg	√ΔP	
	285	.26	3.5/4.4		74		70			86	81	15	.51	
	300	.26	3.5/4.4	499.	74		70			86	81	15	.51	
	315	.26	3.5/4.4		74		70			85	82	15	.51	
	330	.26	3.5/4.4		74		69			86	81	15	.51	
	345	.26	3.5/4.4		76		70			86	81	15	.51	
	360	.26	3.5/4.3		78		70			85	81	15	.51	
	375	.26	3.5/4.4		76		70			88	81	15	.51	
	390	.26	3.5/4.3		77		71			87	81	15	.51	
	405	.26	4.3		76		72			83	81	10	.51	
	420	.26	4.4	621.32	75		73			85	81	10	.51	
	435	.26	4.4		75		75			87	81	10	.51	
	450	.26	4.4		75		73			88	81	10	.51	
	465	.26	4.4		75		73			87	81	10	.51	
off	480													
				689.135										
AVG/TOTAL	480	.26	3.5/4.5	468.736	74					84			.51	

Form EED-021 1/79

5/23/79

PARTICULATE CALCULATIONS

Test 2 8hr.

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$466.483 = 17.64 \frac{465.736}{1.006} \left(\frac{30.05 + \frac{3.5}{13.6}}{74 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{166.4}{Vl_c}$$

7.832 =

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

.017 =

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44 (\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2 + \%CO)$$

28.84 =

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d (1 - B_{wo}) + 18 (B_{wo})$$

28.656 =

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

30.048 =

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s \, MW_s}}$$

$$26.782 = 85.49(.78)(.51)\sqrt{\frac{74 + 460}{(30.048)(28.656)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg} \, A_s \left(\frac{528}{T_s \text{ avg} + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$81{,}380. = 1 - .017 (26.8) \; 51.85 \quad .988 \quad 1.004$$

9. Test percent isokinetic

$$\%I = \frac{17.33 \left(T_s + 460\right) \left[0.04707 \left(Vl_c\right) + Vm_{std}\right]}{\theta \quad V_s \quad P_s \quad D_n^2}$$

$$83.5 = \frac{17.33(534)(7.832 + 466.483)}{480(26.782)(30.048)(.369)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857 \left(Q_s\right) C_s$$

=

12. Percent excess air at sampling point

$$\% \, EA = \frac{100\left[\%O_2 - 0.5 \left(\%CO\right)\right]}{0.264 \left[\%N_2 - \left(\%O_2 - 0.5 \times \%CO\right)\right]}$$

=

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PARTICULATE TEST FIELD DATA SHEET

Plant

Date 5/23/79

Test Location Cooling Tower

Run Number 2 4hr B

Stack Diameter inches 97.5

Duct Dimensions in. x in

Start Time 1240

Operator Raufmann

Barometric Pressure 30.05

Static Pressure -.03" H2O

Stack Pressure

Probe Number

Pitot Coefficient ~.78

Pitot Number

Meter Box Number 084

Orifice Coefficient .683

Nozzle Size & Number ~.307

Molecular Weight 28.84

BWO .020

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO_2	O_2	CO
-	33				
	91.2				
SILICA GEL					
500 260	46.7 ~~28~~17.5				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F							PUMP VACUUM in Hg	√ΔP	
					STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER				
										IN	OUT			
2-10	0	.32	2.9	880.788	68		70			74	74	9	.57	
	15	.32	2.9		68		70			74	74	9	.57	
	30	.33	2.9		68		70			75	75	9	.57	
	45	.32	2.9		67		70			76	75	9	.57	
	60	.32	2.9	933.3	67		70			76	75	9	.57	
	75	.32	2.9		65		70			76	75	9	.57	
	90	.32	2.9		65		69			75	74	9	.57	
	105	.32	2.9		66		70			75	74	9	.57	
	120	.33	3.0		67		70			76	74	9	.57	
	135	.33	3.0		66		70			80	77	9	.57	
	150	.34	3.1		67		70			79	77	10	.58	
	165	.34	3.1		67		70			76	76	7	.56	
	180	.34	3.1	039.64	67		73			76	75	7	.58	
	195	.34	3.0		67		73			76	74	7	.58	
	210	.34	3.0		67		73			76	74	7	.58	
	225	.34	3.0		67		73			76	74	7	.58	
off	240			093.883										
AVG/TOTAL	240		3.0	213.095	67					75			.57	

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5/23/14

PARTICULATE CALCULATIONS Test 2 4hB

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64\ \frac{Vm}{\alpha}\ \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$211.208 = 17.64\ \frac{213.095}{1.007}\left(\frac{30.05 + \frac{3.0}{13.6}}{75 + 460}\right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707\ \overset{91.2}{Vl_c}$$

$$4.293 =$$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$$.020 =$$

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$28.84 =$$

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$$

$$28.623 =$$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$$30.048 =$$

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$

$$29.753 = 85.49(.78)(.57) \sqrt{\frac{67 + 460}{(30.048)(28.623)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg}\ A_s \left(\frac{528}{T_{s\ avg} + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$91{,}399 = \quad .980 \quad 29.8 \quad 51.85 \quad 1.002 \quad 1.004$$

9. Test percent isokinetic

$$\%I = \frac{17.33 \left(T_s + 460\right)\left[0.04707 \left(Vl_c\right) + Vm_{std}\right]}{\theta\ V_s\ P_s\ D_n^2}$$

$$97.3 = \frac{17.33(527)(4.293 + 211.208)}{240(29.753)(30.048)(.307)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857 \left(Q_s\right) C_s$$

=

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\left[\%O_2 - 0.5\ (\%CO)\right]}{0.264\left[\%N_2 - (\%O_2 - 0.5 \times \%CO)\right]}$$

=

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PARTICULATE TEST FIELD DATA SHEET

Plant

Date 5/23/79

Test Location Cooling Tower

Run Number 2 4hr. A

Stack Diameter inches 97.5

Duct Dimensions in. x in.

Start Time 0812

Operator Kartmann

Barometric Pressure 30.05

Static Pressure -.03" H2O

Stack Pressure

Probe Number

Pitot Coefficient ~.78

Pitot Number

Meter Box Number .084

Orifice Coefficient .683

Nozzle Size & Number .357

Molecular Weight 28.84

BWO .020

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO2	O2	CO
–	22				
–	27				
	91.0				
SILICA GEL					
210 200	450 9.0				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F							PUMP VACUUM in. Hg	√ΔP	.003/16"
					STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT			
Sta2-10	0	.31	2.7	674.975	64		61			62	62	4	.56	
	15	.31	2.7		63		61			63	63	4	.56	
	30	.31	2.7		63		60			66	64	4	.56	
	45	.31	2.8		63		63			68	66	4	.56	
	60	.32	2.8	724.55	64		64			69	67	4	.57	
	75	.32	2.9		64		65			70	68	5	.57	
	90	.32	2.9		65		66			71	69	5	.57	
	105	.32	2.9		65		66			71	70	5	.57	
	120	.32	2.9	778.4	66		67			73	71	5	.57	
	135	.31	2.8		66		69			74	72	4	.56	
	150	.31	2.8		67		71			76	73	4	.56	
	165	.31	2.8		67		73			75	74	9	.56	
	180	.31	2.8	828.9	67		72			77	74	10	.56	
	195	.31	2.8		67		72			78	75	10	.56	
	210	.31	2.8		67		73			78	76	10	.56	
	225	.31	2.8		68		73			78	76	10	.56	
off	240			880.640										
AVG/TOTAL		.31	2.8	205.665	65					71			.56	

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5/23/79

PARTICULATE CALCULATIONS

Test 2 4h A

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$205.279 = 17.64 \frac{205.665}{1.007} \left(\frac{30.05 + \frac{2.8}{13.6}}{71 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{91.0}{Vl_c}$$

$$4.283 =$$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$$.020 =$$

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44 (\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2 + \%CO)$$

$$28.84 =$$

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d (1 - B_{wo}) + 18 (B_{wo})$$

$$28.623 =$$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$$30.048 =$$

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s \, MW_s}}$$

$$29.175 = 85.49(.78)(.56)\sqrt{\frac{65 + 460}{(30.048)(28.623)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg} \, A_s \left(\frac{528}{T_s \text{ avg} + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$89{,}917. = \quad .98 \quad 29.2 \quad 51.85 \quad 1.006 \quad 1.004$$

9. Test percent isokinetic

$$\%I = \frac{17.33 \left(T_s + 460\right)\left[0.04707 \left(Vl_c\right) + Vm_{std}\right]}{\theta \quad V_s \quad P_s \quad D_n^2}$$

$$96.2 = \frac{17.33(525)(4.283 + 205.279)}{240(29.175)(30.048)(.307)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857 \left(Q_s\right) C_s$$

=

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\left[\%O_2 - 0.5 \ (\%CO)\right]}{0.264\left[\%N_2 - (\%O_2 - 0.5 \times \%CO)\right]}$$

=

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5/23/79

ISOKINETIC SAMPLING RATE CALCULATION

$$\Delta H = \left(\frac{60^2\ \pi^2 K_p{}^2 C_p{}^2 (1-B_{wo})^2 P_s M_d}{576^2 K_o{}^2 M_s P_m}\right) (N_d{}^4) \left(\frac{T_m}{T_s}\right) (\Delta P)$$

$$\Delta H = (K)(N_d{}^4)\left(\frac{T_m}{T_s}\right)(\Delta P)$$

$$K = \left(\frac{60^2\ \pi^2 K_p{}^2 C_p{}^2 (1-B_{wo})^2 P_s M_d}{576^2 K_o{}^2 M_s P_m}\right)$$

$$= \left(\frac{60^2\ \pi^2\ 85.49^2 C_p{}^2 (1-B_{wo})^2 P_s M_d}{576^2 K_o{}^2 M_s P_m}\right)$$

$$= \left(\frac{782.687\ C_p{}^2 (1-B_{wo})^2 P_s M_c}{K_o{}^2 M_s P_m}\right)$$

Sta. 2
Cp = .78
Ko = .688
K = 994.246
K(Nd)^4 = 8.832
Nd = .307

Sta. 3
Cp = .78
Ko = .722
K = 889.735
K(Nd)^4 = 16.496
Nd = .369

Sta. 2 $= \left(\frac{782.687\ (.78)^2(1-.016)^2(30.05)(28.84)}{(.683)^2(28.67)(30.05)}\right)$

Sta. 3 $= \left(\frac{782.687(.78)^2(1-.016)^2(30.05)(28.84)}{(.722)^2(28.67)(30.05)}\right)$

$$N_d = \left(\frac{\Delta H\ \ T_s}{K\ T_m\ \ \Delta P}\right)^{0.25}$$

=

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PARTICULATE TEST FIELD DATA SHEET

Plant

Date 5/23/79

Test Location Cooling Tower

Run Number 3 4hr A

Stack Diameter inches 97.5

Duct Dimensions in. x in.

Start Time 0800

Operator Rautmann

Barometric Pressure 30.22

Static Pressure -.03" H2O

Stack Pressure

Probe Number

Pitot Coefficient ~.78

Pitot Number

Meter Box Number 084

Orifice Coefficient .683

Nozzle Size & Number .307

Molecular Weight 28.84

BWO .017

FILTER DATA

NUMBER	TARE	FINAL WT.

IMPINGER VOLUMES		TIME	CO2	O2	CO
—	25				
—	6				
	76.0				
SILICA GEL					
250	45				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in. Hg	√ΔP	
2-10	0	.30	2.6	095.099	59		62			60	60	7	.54	002/16"
	15	.29	2.6		59		62			61	60	7	.54	
	30	.30	2.7		59		62			63	61	7	.55	
	45	.30	2.7		60		61			64	62	7	.55	
	60	.30	2.7	145.2	60		61			66	64	7	.55	
	75	.31	2.8		60		62			67	65	8	.56	
	90	.31	2.8		60		62			68	66	8	.56	
	105	.31	2.8		60		62			69	67	8	.56	
	120	.31	2.8	195.80	60		62			69	67	8	.56	
	135	.31	2.8		60		63			70	68	8	.56	
	150	.31	2.8		60		63			70	68	8	.56	
	165	.31	2.8		63		64			71	69	8	.56	
	180	.31	2.8	247.13	62		64			73	70	8	.56	
	195	.31	2.8		62		65			75	72	8	.56	
	210	.31	2.8		62		65			75	72	8	.56	
	225	.31	2.8		64		65			76	73	8	.56	
off	240			298.652										
AVG/TOTAL	240		2.8	203.593	61					65			.56	

[illegible]

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5/23/79
Test 3 4hr A

PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$206.688 = 17.64 \frac{203.593}{1.007} \left(\frac{30.22 + \frac{2.8}{13.6}}{65 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{76.0}{Vl_c}$$

3.577 =

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

.017 =

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44 (\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2 + \%CO)$$

28.84 =

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d (1 - B_{wo}) + 18 (B_{wo})$$

28.656 =

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

30.218 =

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s \; MW_s}}$$

$$28.965 = 85.49(.78)(.56)\sqrt{\frac{61 + 460}{(30.218)(28.656)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg} \; A_s \left(\frac{528}{T_s \; avg + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$90{,}739. = .983 \quad 29. \quad 51.85 \quad 1.013 \qquad \frac{30.22}{29.92}$$

1.01

9. Test percent isokinetic

$$\%I = \frac{17.33 \left(T_s + 460\right) \left[0.04707 \left(Vl_c\right) + Vm_{std}\right]}{\theta \quad V_s \quad P_s \quad D_n{}^2}$$

$$95.9 = \frac{17.33(521)(3.577 + 206.688)}{240(28.965)(30.218)(.307)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857 \left(Q_s\right) C_s$$

=

12. Percent excess air at sampling point

$$\%\,EA = \frac{100\left[\%O_2 - 0.5\ (\%CO)\right]}{0.264\left[\%N_2 - (\%O_2 - 0.5 \times \%CO)\right]}$$

=

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PARTICULATE TEST FIELD DATA SHEET

Plant
Date 5/23/79
Test Location Cooling tower
Run Number 3 4 hr B
Stack Diameter inches 97.5
Duct Dimensions in x in
Start Time 1215
Operator Kaufmann

Barometric Pressure 30.22
Static Pressure - .03" H2O
Stack Pressure
Probe Number
Pitot Coefficient ~.78
Pitot Number
Meter Box Number 084
Orifice Coefficient 1.683

Nozzle Size & Number .307
Molecular Weight 28.84
BWO

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO_2	O_2	CO
–	28				
–	–				
	83.5				
SILICA GEL					
250	55.5				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in wg	ORIFICE METER ΔH in wg	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in Hg	√ΔP	.003/16"
2-10	0	.31	2.8	298.882	67		68			74	73	10	.56	
	15	.31	2.8		67		70			79	77	10	.56	
	30	.32	2.9		67		73			80	78	10	.57	
	45	.33	3.0		67		74			85	80	10	.57	
	60	.33	3.0		67		72			87	82	10	.57	
	75	.33	3.0		68		70			89	85	10	.57	
	90	.33	3.0		68		70			91	87	10	.57	
	105	.33	3.1		67		72			93	89	11	.57	
	120	.33	3.1		65		73			93	90	11	.57	
	135	.33	3.1		63		74			95	92	11	.57	
	150	.33	3.0		63		76			91	90	11	.57	
	165	.33	3.0		64		76			88	87	11	.57	
	180	.33	3.0		64		77			87	86	11	.57	
	195	.33	3.0		65		77			87	86	11	.57	
	210	.33	3.0		65		78			86	85	11	.57	
	225	.33	3.0		65		76			85	84	11	.57	
off	240			513.251										
AVG/TOTAL	240		3.0	214.369	66					86			.57	

5/23/79
Test 3 4hr B

PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$209.359 = 17.64 \frac{214.369}{1.007} \left(\frac{30.22 + \frac{3.0}{13.6}}{86 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{83.5}{Vl_c}$$

$$3.930 =$$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$$.018 =$$

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$28.84 =$$

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$$

$$28.645 =$$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$$30.218 =$$

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s \ MW_s}}$$

$$29.629 = 85.49(.78)(,57)\sqrt{\frac{66 \quad + 460}{(30.218)(28.645)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg} \ A_s \left(\frac{528}{T_s \ avg + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$91,698. = \quad .582 \quad 29.6 \ 51.85 \quad 1.004 \quad 1.01$$

9. Test percent isokinetic

$$\%I = \frac{17.33 \ \left(T_s + 460\right) \left[0.04707 \ \left(Vl_c\right) + Vm_{std}\right]}{\theta \quad V_s \quad P_s \quad D_n^2}$$

$$96.0 = \frac{17.33(526)(3.930 + 209.359)}{240(29.629)(30.218)(.307)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \ \frac{M_p}{Vm_{std}}$$

=

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857 \ (Q_S) \ C_S$$

=

12. Percent excess air at sampling point

$$\% \ EA = \frac{100\left[\%O_2 - 0.5 \ (\%CO)\right]}{0.264 \ [\%N_2 - (\%O_2 - 0.5 \times \%CO)]}$$

=

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PARTICULATE TEST FIELD DATA SHEET

Plant
Date 5/23/79
Test Location Cooling Tower
Run Number 3 8hr
Stack Diameter inches 97.5
Duct Dimensions in. x in.
Start Time 0800
Operator Kaufmann

Barometric Pressure 30.22
Static Pressure -.03" H2O
Stack Pressure
Probe Number
Pitot Coefficient ~.78
Pitot Number
Meter Box Number 015
Orifice Coefficient .722

Nozzle Size & Number .369
Molecular Weight 28.84
BWO

FILTER DATA

NUMBER	TARE	FINAL WT.

IMPINGER VOLUMES		TIME	CO2	O2	CO
—	34				
—	—				
	153.5				
SILICA GEL					
250 300	141.0 [illegible]				

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER IN	GAS METER OUT	PUMP VACUUM in Hg	√ΔP	003/16"
4-10	0	.25	3.7/4.1	689.558	64		62			63	63	15	.50	
	15	.25	3.2/4.1		65		62			70	65	15	.50	
	30	.24	4.0		65		62			74	67	19	.49	
	45	.24	4.0		66		61			77	69	19	.49	
	60	.24	4.0	750.54	66		61			79	71	19	.49	
	75	.24	4.0		68		62			82	73	19	.49	
	90	.24	4.0		68		63			81	74	19	.49	
	105	.24	4.0		68		62			81	74	19	.49	
	120	.24	4.0	814.95	68		63			81	74	19	.49	
	135	.24	4.0		69		63			81	75	19	.49	
	150	.24	4.0		68		64			82	75	19	.49	
	165	.24	4.0		70		64			84	76	19	.49	
	180	.24	4.0	879.40	69		64			84	77	19	.49	
	195	.24	4.0		69		65			85	78	19	.49	3444
	210	.24	4.0		69		65			86	78	19	.49	
	225	.24	4.0		73		65			86	79	19	.49	786
off	240			943.998										
	240	.24	4.0	943.998	77		68			80	79	17	.49	
	255	.24	4.0		74		70			85	79	17	.49	
	270	.24	4.0		75		73			87	80	17	.49	
AVG/TOTAL														

11.492

Form EED 121 1/79

ACUREX Corporation

PARTICULATE TEST FIELD DATA SHEET

Plant
Date 5/23/79
Test Location cooling tower
Run Number test 3 8h
Stack Diameter inches
Duct Dimensions in. x in.
Start Time
Operator Rautmann

Barometric Pressure
Static Pressure
Stack Pressure
Probe Number
Pitot Coefficient
Pitot Number
Meter Box Number
Orifice Coefficient

Nozzle Size & Number
Molecular Weight
BWO

FILTER DATA

NUMBER	TARE	FINAL WT

IMPINGER VOLUMES		TIME	CO_2	O_2	CO
SILICA GEL					

SAMPLE POINT	CLOCK TIME	VELOCITY HEAD ΔP in. wg	ORIFICE METER ΔH in. wg	GAS METER VOLUME FT³	TEMPERATURES °F							PUMP VACUUM in. Hg	√ΔP	
					STACK	PROBE	IMPINGER	ORGANIC MODULE	OVEN	GAS METER				
										IN	OUT			
	285	.24	4.0		73		74			89	81	17	.49	
	300	.24	4.0		75		72			91	82	17	.49	
	315	.24	4.1		73		70			95	85	18	.49	
	330	.24	4.1		73		70			96	86	18	.49	
	345	.24	4.0		74		72			96	88	17	.49	
	360	.24	4.1		73		73			96	88	18	.49	
	375	.24	4.1		74		74			99	89	18	.49	
	390	.24	4.0		76		76			96	89	17	.49	
	405	.24	4.0		76		78			96	89	17	.49	
	420	.24	4.0		77		78			95	89	17	.49	
	435	.24	4.1		75		78			96	90	17	.49	
	450	.24	4.1		75		78			97	90	17	.49	
	465	.24	4.1		74		77			95	90	17	.49	
off	480			265.198										
AVG/TOTAL	480		4.0	515.640	74					83			.49	

Form [illegible] 1-79

Test 3 8hr

PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \frac{P_b + \frac{\Delta H}{13.6}}{Tm + 460}$$

$$508.099 = 17.64 \frac{515.640}{1.006} \left(\frac{30.22 + \frac{4.0}{13.6}}{83 + 460} \right)$$

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707 \overset{153.5}{Vl_c}$$

$$7.225 =$$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$$.014 =$$

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44 (\%CO_2) + 0.32 (\%O_2) + 0.28 (\%N_2 + \%CO)$$

$$28.84 =$$

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d (1 - B_{wo}) + 18 (B_{wo})$$

$$28.688 =$$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$$30.218 =$$

ACUREX Corporation

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49 \left(C_p\right)\left(\sqrt{\Delta P}\right)_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$

$$25.644 = 85.49(.78)(.49)\sqrt{\frac{74 + 460}{(30.218)(\quad)}}$$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60 \left(1 - B_{wo}\right) Vs_{avg}\ A_s \left(\frac{528}{T_{s\ avg} + 460}\right)\left(\frac{Ps}{29.92}\right)$$

$$= \quad .986 \quad 25.6 \quad 51.85 \quad .989 \quad 1.01$$

9. Test percent isokinetic

$$\%I = \frac{17.33 \left(T_s + 460\right) \left[0.04707 \left(Vl_c\right) + Vm_{std}\right]}{\theta \quad V_s \quad P_s \quad D_n^2}$$

$$94.2 = \frac{17.33(534)(7.225 + 508.099)}{480(25.644)(30.218)(.369)^2}$$

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}}$$

$$=$$

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857 \left(Q_s\right) C_s$$

$$=$$

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\left[\%O_2 - 0.5\ (\%CO)\right]}{0.264\left[\%N_2 - (\%O_2 - 0.5 \times \%CO)\right]}$$

$$=$$

ACUREX Corporation

5/24/79

ISOKINETIC SAMPLING RATE CALCULATION

$$\Delta H = \left(\frac{60^2 \pi^2 K_p{}^2 C_p{}^2 (1-B_{wo})^2 P_s M_d}{576^2 K_o{}^2 M_s P_m}\right) (N_d{}^4) \left(\frac{T_m}{T_s}\right) (\Delta P)$$

$$\Delta H = (K) (N_d{}^4) \left(\frac{T_m}{T_s}\right) (\Delta P)$$

Sta 2

K = 994.246

K(Nd)^4 = 8.832

Nd : .307

$$K = \left(\frac{60^2 \pi^2 K_p{}^2 C_p{}^2 (1-B_{wo})^2 P_s M_d}{576^2 K_o{}^2 M_s P_m}\right)$$

Sta 4

K = 889.735

K(Nd)^4 = 16.496

Nd = .369

$$= \left(\frac{60^2 \pi^2 85.49^2 C_p{}^2 (1-B_{wo})^2 P_s M_d}{576^2 K_o{}^2 M_s P_m}\right)$$

$$= \left(\frac{782.687\ C_p{}^2 (1-B_{wo})^2 P_s M_d}{K_o{}^2 M_s P_m}\right)$$

sta 2 $= \left(\frac{782.687\ (.78)^2 (1-.016)^2 (30.22)\ (28.84)}{(.683)^2 (28.67)\ (30.22)}\right)$

sta 4 $= \left(\frac{(782.687)(.78)(1-.016)^2 (30.22)(28.84)}{(.722)^2 (28.67)(30.22)}\right)$

$$N_d = \left(\frac{\Delta H \quad T_s}{K\ T_m \quad \Delta P}\right)^{0.25}$$

$=$

ACUREX
Corporation

Date 9/25/78
Time 840
Barometric Pressure 30.05
Ambient Temperature 73 °F

Orifice Meter 426275
Orifice Magnehelic 40725AM7
Primary Calibration Meter 259453
Control Module 0015

Operator Gilchrist
Wet Bulb Temperature

Orifice Plate # C049

METER CALIBRATION DATA

Orifice Manometer ΔH_mp (in. wg.)	Orifice Magnehelic ΔH_D (in. wg.)	Primary Meter ΔP_p (in. wg.)	Dry Test Meter P_dg (in. wg.)	Gas Volume Primary Meter V_p (ft.³)	Gas Volume Dry Test Meter V_d (ft.³)	Temperature: Primary Meter Inlet, t_pi (°F)	Primary Meter Outlet, t_po (°F)	Primary Meter Avg., t_pm (°F)	Dry Test Meter Inlet, t_di (°F)	Dry Test Meter Outlet, t_do (°F)	Dry Test Meter Avg., t_dm (°F)	Time θ (min.)	γ	ΔH@
.81	.8			264.309 244.585	043.251 023.671	80 73	76 73	75.50	76 73	75 73	74.25	15	[illegible]	.814
				19.724	19.580									
1.80	1.8			[illegible] 264.309	[illegible] 043.251	83 82	75 76	[illegible]	77 76	77 75	[illegible]	10	[illegible]	[illegible]
				19.135	18.980									
2.80	[illegible]			[illegible] 283.[illegible]	[illegible] 062.251	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]
				11.861	11.764									
3.81	2.8			[illegible] 296.366	[illegible]	[illegible]	[illegible]	[illegible]	78 [illegible]	78 77	[illegible]	5	[illegible]	[illegible]
	1.6			13.729	[illegible]									
.8[illegible]	.8			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				11.526	11.366									
1.8[illegible]	1.8			[illegible] [illegible].366	[illegible] 098.965	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]	[illegible]
				[illegible]	[illegible]									
2.79	2.8			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	[illegible]	[illegible]
				11.215	11.103									
3.81	3.8			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				12.863	10.764									
.80	.8			[illegible]	[illegible] 133.718	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				21.405	[illegible]									
1.80	1.8			[illegible]	[illegible]	[illegible]	[illegible]	97.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				15.452	15.[illegible]									
2.79	2.8			[illegible] [illegible].306	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				14.175	14.[illegible]									
3.81	3.8			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.75	[illegible]	[illegible]	[illegible]
				1[illegible].219	16.320									
													Average	

red
.281

small
.187

large
.356

α = 1.009
ΔH@ 1.822

.722

α = 1.021
ΔH@ 3.640

DATE 2-6-79
TIME 0850
BAROMETRIC PRESSURE 30.30
AMBIENT TEMP 46 °F

TEST PITOT TUBE
STANDARD PITOT TUBE United Sensor
TEST SECTION LOCATION Windtunnel
OPERATORS Seegmiller + Gilchrist

NOZZLE SIZE
NOZZLE-PITOT SPACING
PITOT-TC SPACING

PITOT TUBE CALIBRATION DATA

P 38

Test Pitot Tube ΔP (in. wg.)		Standard Pitot Tube ΔP (in. wg.)	C_p	Static Pressure (in. wg.)	Gas Temp (°F)	Wet Bulb Temp (°F)	Test Section Velocity (fps)
Upper Leg	Lower Leg						
1.48 .793	1.48 .777	.95"H2O					
1.20 .773	1.17 .809	.77					
.82 .796	.82 .796	.53					
.53 .793	.52 .801	.34					
.26 .821	.24 .833	.17					

Average C_p, upper = .795   Average C_p, lower = .806

DATE 2-6-79
TIME 0821
BAROMETRIC PRESSURE 30.30
AMBIENT TEMP 46° F

TEST PITOT TUBE
STANDARD PITOT TUBE United Sensor
TEST SECTION LOCATION Windtunnel
OPERATORS Seegmiller + Gilchrist

NOZZLE SIZE
NOZZLE-PITOT SPACING
PITOT-TC SPACING

PITOT TUBE CALIBRATION DATA

P37

Test Pitot Tube ΔP (in. wg.)		Standard Pitot Tube ΔP (in. wg.)	C_p	Static Pressure (in. wg.)	Gas Temp (°F)	Wet Bulb Temp (°F)	Test Section Velocity (fps)
Upper Leg	Lower Leg						
.18 [illegible]	.18 [illegible]	.12"H₂O					
~~[illegible]~~ .55 [illegible]	.56 [illegible]	.35					
.92 [illegible]	.83 [illegible]	.56					
1.16 [illegible]	1.12 [illegible]	.73					
1.50 [illegible]	1.50 [illegible]	.97					

Average $C_{p, upper}$ = .784

Average $C_{p, lower}$ = .715

VELOCITY / TEMPERATURE PROFILE 5-21-79

- B.C. DARES

STACK DIAM = 97.5" STACK HEIGHT = 10."

~.78 C_p

STA. #	INCH.	STATION IN. H_2O - TEMP (°F) A ①		B ②		C ③		D ④	
1	1 1/16	.055	73	.15	69	.05	70	.03	72
2	3 1/16	.11	74	.21	70	.09	72	.03	74
3	5 3/8	.165	72	.26	69	.15	73	.07	73
4	7 11/16	.26	71	.38	68	.36	72	.11	73
5	10 1/4	.31	70	.38	68	.33	71	.23	72
6	12 7/8	.325	69	.38	67	.32	70	.32	72
7	15 11/16	.35	68	.33	67	.28	69	.41	70
8	18 15/16	.35	68	.40	67	.26	68	.40	69
9	22 3/8	.29	68	.42	67	.23	68	.36	68
10	26 1/2	.11	67	.25	67	.20	67	.26	68
11	31 1/2	.14	68	.13	67	.16	67	.10	68
12	38 13/16	.02	68	.02	68	.02	67	.00	68
13	50.70								
14	66.01	.207		.276		242		.193	
15	70.98	$.413\sqrt{\Delta p}$		$.505\sqrt{\Delta p}$		$.430\sqrt{\Delta p}$		$.391\sqrt{\Delta p}$	
16	75.08		avg =	$.435(\sqrt{\Delta p})_{avg}$					
17	78.57								
18	81.60		$\frac{836}{12}$		$\frac{814}{12}$		$\frac{834}{12}$		$\frac{847}{12}$
19	84.63		67		68		70		71
20	87.26								
21	89.80			69.°F avg					
22	92.14								
23	94.38								
24	96.43								

5-24-79 B.C. DuRos

DESCRIPTION OF PROCESS

→ Change Charge - requires approx 30 min to switch loads.

→ Steam Condition - Not used

→ Vacuum - 15 min - This process serves to seat the door seal and gives the operator time to check for open valves.

→ Oil Condition - oil is pumped in to cover poles and then heated to predetermined temperature:

Fir 210 to 220°F Cedar 170°F
Dry to wet

Vacuum is also applied to draw water from logs (sap wood):

Dry Cedar 15 to 18 hrs
Fir up to 50 hrs if wet and thick sap wood layer.

Length of time is actually determined by water flow rate (water extracted from poles) when flow drops to predetermined rate oil cond. process is terminated and oil is pumped out.

→ Air pressure - 15 to 30 PSI - dry cell treatment.

→ Pressure Period - Oil is pumped in while maintaining air pressure - retort is pumped full. Next oil is pumped in under pressure until a predetermined amount (gallons) has been pressed into the poles.

110 PSI - Fir

80 PSI - Cedar

[Operator Note: Operator states that they are lucky to get 80% of oil required for cedars pumped in]

After predetermined amount of oil is pumped in pressure is released and oil is pumped out until poles are just covered.

→ Vacuum - remainder of oil is pumped out creating a partial vacuum, then max vacuum is applied for (22 to 26" Hg) for 30 min.

→ Steam - (For Fir Only) - live steam is injected at 240°F for 3 hrs - this cleans and drys the poles.

→ Vacuum - 1 hr at Max vacuum to remove final traces of oil and moisture (1 hr for cedar or fir)

Notes on Process:

Oil is 5% penta-chlorophenol dissolved in Medium aromatic treating oil.

Penetration varies as a function of sap wood thickness and moisture content. Processors try to achieve 80% penetration of sapwood on fir cedar is usually 100% penetrated.

Retort: 8 feet - diameter 144 feet long

CREO - creosote
ACA - chemonite
ACP-L - light
PCP-H - Heavy

Cooling Tower - Thermal Data 5-24-79

0930 - time

Cold water temp @ sump 62.°F

Ambient Wet bulb temp 55°F

Ambient Dry bulb temp 61°F

Fan Wet bulb 59.°F

Fan Dry bulb 61.°F

Flow from water/oil separator 0900

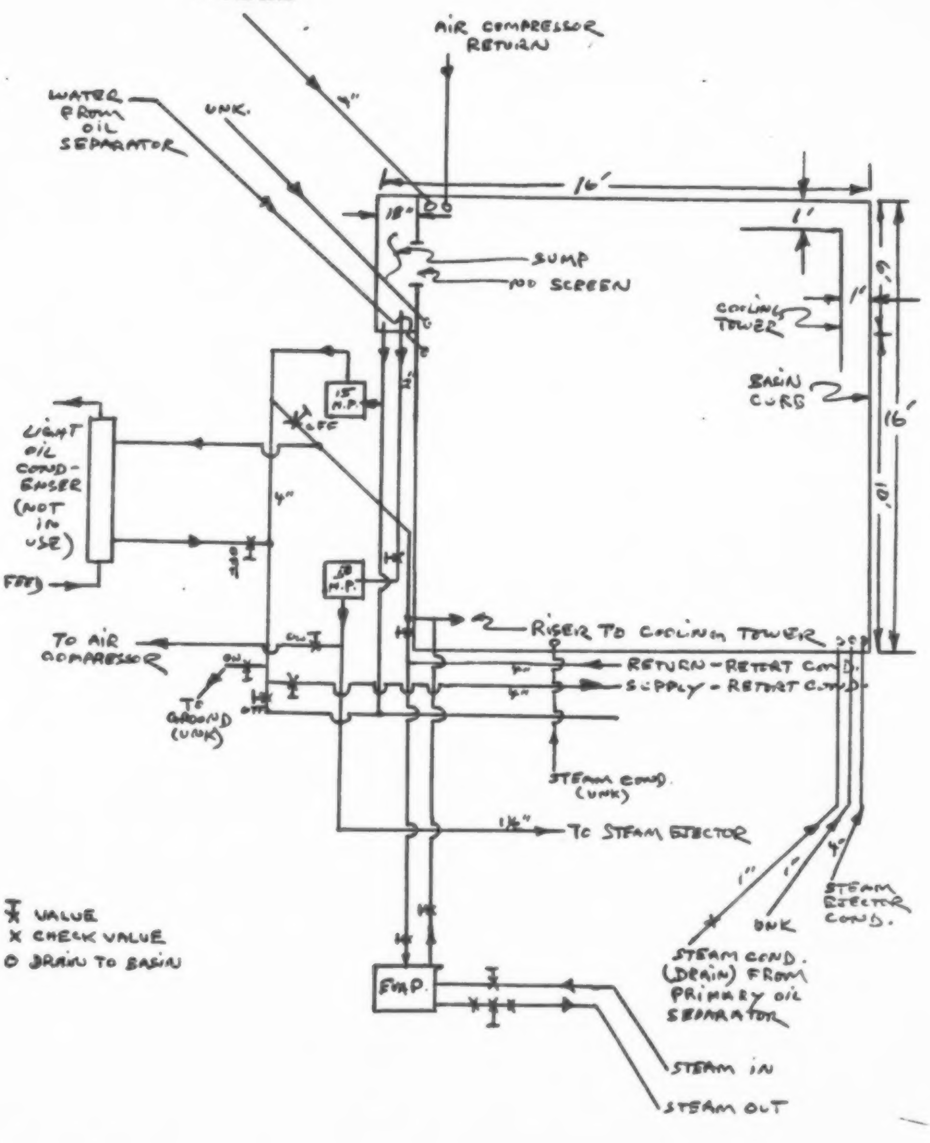
$$5\text{ gal}\quad \left.\begin{array}{l}17.0\\17.5\\18.0\end{array}\right\}\text{secs}\qquad\therefore\quad \frac{60}{17.5}\times 5 = 17.\text{ gpm}$$

temp = 108°F @ 0900

B.C. DuRos

DIAGRAM: COOLING TOWER-STRIPPER

5-22-79


BOILER RESEVOIR OVERFLOW
AIR COMPRESSOR RETURN
WATER FROM OIL SEPARATOR
UNK.
4"
16'
18"
1'
SUMP
NO SCREEN
COOLING TOWER
1'
6'
BASIN CURB
16'
10'
15 H.P.
2"
OFF
LIGHT OIL CONDENSER (NOT IN USE)
4"
FEED
10 H.P.
ON
RISER TO COOLING TOWER
TO AIR COMPRESSOR
ON
OFF
TO GROUND (UNK)
4"
4"
RETURN - RETORT COND.
SUPPLY - RETORT COND.
STEAM COND. (UNK)
1½"
TO STEAM EJECTOR
1"
1"
4"
STEAM EJECTOR COND.
UNK
STEAM COND. (DRAIN) FROM PRIMARY OIL SEPARATOR
EVAP.
STEAM IN
STEAM OUT
VALUE
X CHECK VALUE
O DRAIN TO BASIN

Date in 5-23-79 12:30A

D. FIR POLES 2554 ft^3 Condition - S. wet

Preservative - PCP-A Size - Large

Record of operation:

	Max Temp	Max pres.	Vac	Start Time	Duration
change charge				12:30 A	:30
steam condition					
vacuum			5½"	1:00A	:15
oil condition	220°F		23"	1:15A	28 :45
air pressure		15#		6:00A	:30
pressure period	185°F	110#		6:30A	2:00
expansion bath	210°F		23½	8:30A	5:00
vacuum				11:00A	:30
steam	240°F			2:00P	3:00
vacuum				5:00	1:00

2:30 hr extra on expansion bath - Boiler was down for repairs.

Recorded by B. L. DeRon 5-24-79

DATE IN 5-21-79 11:00 A
D. FIR POLES 2791 ft³ Condition - wet
Preservative - PCP-A Size - Medium

Record of operation:

	max Temp	max pres.	Vac.	Start time	Duration
charge charge				11:00A	:30
steam condition					
vacuum			5."	11:30A	:15
oil condition	220°F		23."	11:45A	27:45
air pressure		15#		3:30P	:30
pressure period	190°F	110#		4:00	
expansion bath	210°F		23.5"	5:15	2:30
vacuum				7:45	:30
steam	240°F			8:15	3:00
vacuum				11:15	1:00
					37.15

Record by Ben Dalton 5-22-79

Stabilite-WA   49-168

N-Tallow-1,3-Diaminopropane

Reichhold Chemicals, Inc.
Tacoma, Wash.

Reichhold Chem. Inc.
525 North Broadway
White Plains, NY 10602

supposed to improve the appearance of the pole
upon removal from retort.

2-5 gal pails per batch of oil (5000 to 6000 gal)